DECISION SUPPORT SYSTEM FOR VENEER AND PLYWOOD PRODUCTION AND MARKETING

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Abstract

This study presents a methodology for planning log purchases, production strategies and market policies in a radiata pine (*Pinus radiata* D. Don) veneer and plywood plant in New Zealand. It develops resource, production and marketing-oriented linear programming (LP) models (LOGPLY, logs to plywood model and VENPLY, veneer to plywood model) that can be used as real time decision support systems in a microcomputer (PC) environment. These models address the global decision-making needs for strategic, tactical and operational planning horizons in veneer and plywood operations. The modelling also encompasses veneer recovery of radiata pine by log source, type and small end diameter (SED) class and by veneer thickness. These factors are necessary to structure an efficient LOGPLY modelling system that can evaluate the effects of log type proportions and SED classes in relation to the economic profitability of the operation. Total veneer recovery yield, according to log source, log type, SED class and veneer peel thickness have been modelled using multiple linear regressions that incorporate dummy variables. Time studies for new material categories (e.g. SED class, type of corestocks, panel thickness, etc.) in major machine centres to measure appropriate production have also been conducted in order to best capture the effect of production aspects of the operations in the models. Maximum and minimum sales constraints by panel grade and thickness are included to reflect fully the importance of the market impact on veneer and plywood operations and to demonstrate the concept of market-oriented manufacturing. LOGPLY and VENPLY are formulated in consistent standards of measurement to ease validation and interpretation of results. The models have special constraint structure sets manifested by a nested (multicoupled) angular coefficient structure that accommodates the *de novo* programming approach or soft optimisation to design optimal systems rather than merely optimising a specified fixed system. VENPLY acts as a complementary model to LOGPLY and as a second-stage optimiser.

LOGPLY and VENPLY working models are implemented in a spreadsheet environment (Quarttro Pro 3.0) and an add-on LP package, Beeline on PC (at least 1 Mb of RAM and 80286). This provides real time systems that managers and decision makers can use to simulate production and market conditions routinely, by updating the technological and resource coefficients of the models without the help of operations research personnel. The user-friendliness of the system for people familiar with spreadsheets is emphasised.

Five LOGPLY case studies and four VENPLY case studies are investigated using *de novo* optimisation or a soft optimisation approach by way of demonstration of a real plant. The LOGPLY case studies reveal that: i) designing an optimal system from an

already optimised base case with the same product mix can result in increased revenue by 5 percent; ii) optimising a given system with market demand variation ($\pm$ 50 % of individual product grade and thickness of the base case product mix) can result in increased revenue by 3.5 percent over optimised base case; iii) designing an optimal system with product (A and B veneer sales) and market demand variation from the optimised base case has increased the revenue by 13.6 percent; and iv) designing for the ideal system from the optimised base case has increased the revenue by 43 percent. The VENPLY case studies reveal that: i) designing an optimal system with the same machine time availability as the base case has increased the revenue by 6.7 percent over the base case; ii) designing an optimal system without production (machine) constraints has increased the revenue by 28.7 percent over the base case; iii) designing an optimal system with market variation has increased the revenue by 37 percent over the base case.

The study also demonstrates the capabilities of the models to address the global needs and problems of decision-making in veneer and plywood operations in the area of: i) log allocation \ procurement using LOGPLY; ii) veneer allocation using LOGPLY and VENPLY; iii) layup options and product mix determination using both models; iv) veneer downgrading using both models; v) machine performance and production bottlenecks evaluation using both models; vi) production scheduling and control using both models; and vii) production and market coordination using both models.

Furthermore, the study reveals that veneer and plywood operations do not need to be fed 100 percent pruned logs as claimed in a recent study, but a combination of pruned and unpruned logs. The log mix proportion varies from 40:60 (pruned:unpruned) down to 21:79. The results indicate that veneer and plywood production in New Zealand can be one of the most profitable investments for the nation's radiata pine resource contrary to findings of the recent Forest Industries Strategy Study 1992 conducted by New Zealand Forest Industries Council, but log type proportions must be properly identified to suit the intended or planned product mixes for the markets. One should apply the concept of market-oriented manufacturing as demonstrated in this study.

This study shows new approaches and dimensions which have not been done before in modelling veneer and plywood operations: i) the modelling considers fully the log resource, production and marketing aspects of the operations which makes the models fully effective to address the global needs of decision-making in veneer and plywood operations; ii) the models are formulated in consistent standard of measurement to ease valuation and interpretation of the results; iii) the concept of soft optimisation which has not been applied before in this operation, enchances the utility of the models to address the needs in strategic planning by designing an optimal log procurement strategy in the case of LOGPLY and an optimal veneer allocation without veneer downgrading in the case of VENPLY; iv) the technique of two-stage optimisation using LOGPLY and VENPLY creates opportunities and new perspectives on how to manage the veneer and plywood operation effectively; v) the implemention of LOGPLY and VENPLY in a spreadsheet environment provides real time decision support systems to respond to the needs of solving problems of production scheduling and control in the least possible time; and vi) the study disproves the traditional view point that veneer and plywood operation should be fed with 100 percent pruned logs to be profitable.

Chapter 1

Introduction

1.1 Background of the Study

Veneer and plywood production in New Zealand is considered to be an unprofitable option for investment according to the Forest Industries Strategy Study conducted by New Zealand Forest Industries Council (Edgar *et al.*, 1992). The internal rate of returns (IRR) for this investment for both local and foreign investors appears to be negative. Despite the increasing realisable volume of pruned (P1/P2) radiata pine (*Pinus radiata* D. Don) logs to be harvested as a result of the widespread implementation nationally of the direct sawlog regime (pruned to 6 m and thinned), higher wood and glue costs appear at first sight to make the industry a non-viable investment in New Zealand compared to the United States of America (South) and Canada. The higher wood costs have worsened with the doubling of log export prices in the first quarter of 1993, as a result of aggressive marketing strategies for radiata logs by ITT Rayonier. Despite Canada being the second largest and most efficient softwood veneer and plywood industry, several Canadian veneer and plywood plants are closing (Canadian Lumber Reporter, 1990). The AB plywood plant, Grande Prairie, for example, was closed permanently after 37 years in operation. MacMillan

Bloedel announced it was considering closing its Port Alberni, British Columba plywood plant, saying the mill had turned a profit only 3 times in the past 20 years. Fletcher Challenge Canada Ltd is planning to sell its Delta plywood plant and Richmond Plywood has been searching for a buyer. Fletcher Challenge New Zealand Ltd has sold its veneer and plywood plant in Kinleith, Torokoa (the plant at which data were collected for this study) to Carter Holt Harvey Ltd. The main contributing reasons were said to be the high cost of plywood operations compared with competing panel products, such as fibreboard (MDF), particleboard, waferboard and oriented stand board (OSB); and cheaper plywood from the United States of America. Nevertheless, plywood is preferred in the construction industry for structural uses such as concrete formwork, exterior load bearing walls, and floors of farmhouses. This preference is due to the better mechanical properties and higher strength compared with any other composite wood panel. The major drawback, however, is its price. But, if plywood is reasonably priced, consumers would prefer to buy plywood rather than any other composite panel product, due to its desirable properties.

Radiata pine plywood has been accepted in New Zealand and Australia for some time now. It is gaining acceptance in Japan (JETRO, 1988), Hong Kong and the Pacific Rim. Its mechanical properties are comparable to the dipterocarp plywood produced in Southeast Asian countries and Douglas fir plywood in the United States of America (FRI, 1988). Moreover, radiata veneer is gaining acceptance by some Japanese and North American buyers. With this trend, the prospect of expanding and improving radiata veneer and plywood plants in New Zealand is a real possibility as a source of added value manufacturing. But, competition could occur if and when the Japanese import peeler logs of radiata pine to feed their 200 plywood mills (JETRO, 1988). Acceptance of radiata pine as a useful raw material and pressure not to use tropical hardwoods for environmental reasons, appear to be influencing Japanese strategic thinking. With this development, local veneer and plywood manufacturers should strive to be competitive enough to pay the prevailing peeler log price in New Zealand and export reasonably priced veneer and plywood products in order to earn revenue and gain more market share.

1.2 Statement of the Problem

Veneer and plywood manufacturing involves fairly complex industrial processes (Spelter, 1990). Consequently, changes in the type or size of log used in the product mix to be produced and in the equipment available, can have far-reaching effects on the utilisation of resources within a mill and on its economics. Production managers are always confronted with these changes due to diverse product specifications ordered by sales personnel and due to pressures for rush deliveries of orders. In addition, continual variation in the nature of the log supply in terms of log diameter and log type proportions complicates matters further. In these situations, production managers react spontaneously to fill standing orders and deliver the required mix of goods rather than planning and scheduling the product mix in least costly ways, while maintaining high quality standards and scheduling unallocated production time to the best or most profitable combinations of products. Minor mistakes in decision-making regarding the purchase of logs by type, source and even SED class, output product mix (panel thickness, grade and quantities) and equipment scheduling over any planning horizon will inevitably lead to reduced profitability or even losses. The symptoms may be individually difficult to detect, but the collective effects are often cumulative and eventually lead to a break- even type of production and the early shut down of the plant.

This study has been conducted, therefore, to respond to the need to develop a systematic management approach that would improve the competitive edge of plywood compared with other panel products through addressing problems in the overall operation of veneer and plywood plants. This study develops a real-time computer system to respond to the needs of: i) log procurement and allocation; ii) veneer allocation and valuation; iii) optimal layup and product mix determination; iv) plant capacity planning; v) optimal machine time allocation; vi) production scheduling and control; and vii) coordination of production and marketing.

1.3 Scope of the Study

Veneer and plywood manufacturing is a multi-faceted operation in which decisions right from the time of purchasing logs, through to the use of machines in terms of production rate and machine time allocation, and finally to forecasted product mix for intended markets are all interrelated and critical to the economic profitability and survival of the plant. Managers should consider all available information about raw material resources, the production environment and markets in every possible way before making decisions. Thus, a new approach and methodology for modelling veneer and plywood operation, incorporating all aspects of activities, is desirable to cater for and respond to the needs of current and future overall decision-making in veneer and plywood manufacturing.

This study presents methodologies to develop resource production marketing-oriented linear programming (LP) models (LOGPLY, logs to plywood model and VENPLY, veneer to plywood model) that can be used as real-time decision support systems in a microcomputer (PC) environment to address the global needs of decision-making for strategic, tactical and operational planning horizons in veneer and plywood operations. The study also encompasses veneer recovery modelling of radiata logs by source, type, SED class and veneer thickness. The veneer recovery study is also conducted for the purpose of developing an efficient LOGPLY model and to demonstrates the capabilities of the model not only as a resource-oriented model, but for evaluating the effects of log type proportions, and SED classes in the economic profitability and day to day operation of a plant being studied. Time studies for the new material categories (e.g. SED class for logs, type of corestocks, etc.) in major machine centres to measure the appropriate production rates of the machines are also conducted to represent the production side of the veneer and plywood operation in the models. The concept of market-oriented manufacturing is also presented in the modelling, through implementing the maximum and minimum constraints of the products by grade and thickness to simulate the effects of changing market conditions.

1.4 Objectives of the Study

The specific objectives of the study are as follows:

1. to develop a decision support system (DSS) for log procurement and allocation, for determining optimal product mix, for product costing, for plant capacity planning, for machine performance evaluation and for overall throughput in veneer and plywood production;
2. to develop a decision support system tool that is common to both production planning and marketing;
3. to demonstrate the advantages of soft optimisation or *de novo* programming over the traditional LP programming in veneer and plywood operations.

4. to develop a system that is capable of updating production and market conditions in real-time[1] to minimise production costs and help maximise profits;
5. to develop a system which is flexible to use in the strategic (annually), tactical (monthly) and operational (e.g. weekly) planning horizons;
6. to demonstrate the advantages and opportunities of a market-driven system for veneer and plywood production; and
7. to investigate productivity and profitability options in veneer and plywood production.

Chapter 2 reviews previous studies in veneer and plywood in the areas of veneer recovery and conversion to achieve efficient utilisation of the raw materials, and veneer and plywood operation modelling to achieve economic efficiency. Chapter 3 discusses the data collection necessary to structure an efficient model, specifically for veneer recovery and time studies. The mathematical structure, properties and function of the models formulated are documented in Chapter 4. Chapter 5 discusses how the computer model is implemented in a spreadsheet environment to provide real-time decision-making capability. The utility and capabilities of the models to provide systems which address global needs of decision-making in veneer and plywood are presented and discussed in Chapter 6. Finally, the impact of the study and its recommendations are summarised in Chapter 7.

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[1] Real-time refers to the shortest possible time during which one can reflect and changes in resource, production and market conditions on a computer planning system, evaluate them so as to allow te solution to be used as a basis for making a sound decision regarding the problem involved.

The thesis aims overall to show the areas of veneer and plywood operations on which managers need to focus in order to achieve greater control and economic profitability, and secondly to demonstrate the recent advances in computer hardware and software technology that can be harnessed to provide plywood plant managers with a decision support system that meets the overall needs of decision-making in veneer and plywood operations without the need to rely on modelling experts, except in rare circumstances.

Chapter 2

Modelling in Veneer and Plywood

Veneer and plywood are the most valuable among all wood products in terms of volume to value ratio. In 1991 the New Zealand export average value (free on board) for softwood plywood was \$ 887 per m^3; fibreboard (MDF) was \$ 465 per m^3; particleboard was \$ 398 per m^3; softwood lumber was \$ 323 per m^3; and logs were \$ 98 per m^3 (NZ Forestry Statistics, 1992). Although plywood is the highest value-added of these wood products, it accounted for only 0.5 percent of the total volume of wood products exported, compared with a 6.8 percent share for fibreboard and a 1.7 percent share for particleboard. Lumber accounted for 14.2 percent in volume and 27.9 percent in value of the total wood products exported, almost 26 times the volume but only 9.5 times the value of all plywood (Figure 2-1.A). Although plywood is a relatively expensive product, New Zealand plywood has sold quite well in the Australian market. It occupied a market share of 36 percent compared to Indonesian plywood of 32 percent in 1990 (USDA, 1992). In 1991, however, softwood plywood accounted for 4.7 percent of all major softwood forest products in terms of volume and 7 percent in the total value of major softwood forest products in the United States of America. Lumber accounted for 28.7 percent in volume and 37.7 percent in value. Fibreboard accounted for only 1 percent in volume and for 1.6 percent in value and

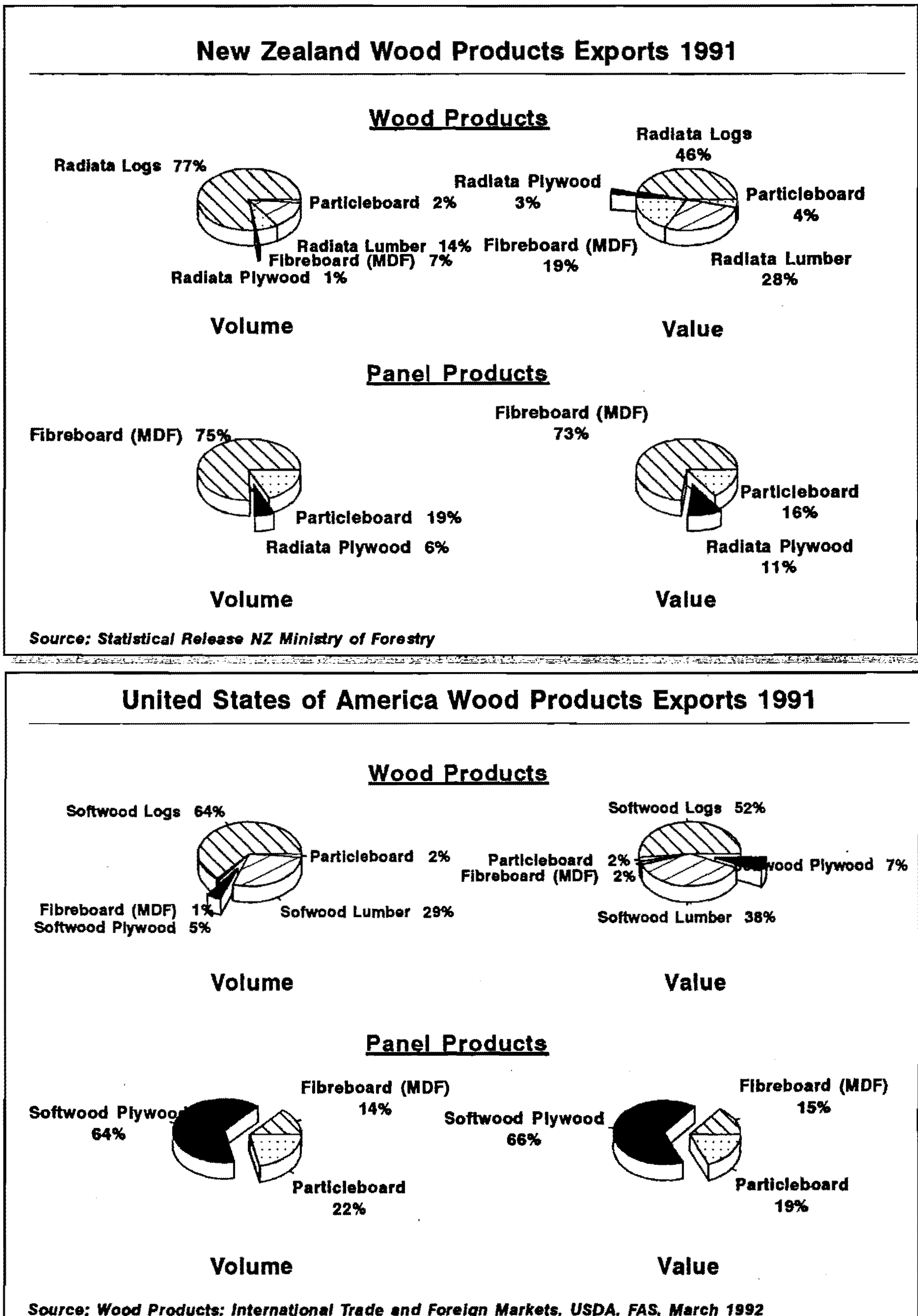


Figure 2-1. Status of Plywood Exports from New Zealand compared with the United States of America.

particleboard accounted for 1.6 percent in volume and 2 percent in value. In the panel products category, plywood accounted for approximately 64 percent in volume, and 66 percent in the value. Particleboard, medium density fibreboard (MDF), and hardboard combined, accounted for 36 percent in volume, but only 34 percent in value as shown in Figure 2-1.B (USDA, Wood Products, 1992). The average export value (free alongside vessel) of US \$ 213 per m^3 for U. S. softwood plywood; moreover, it was lower than the average export value of fibreboard, US \$ 222 per m^3. One possible observation is that U.S. plywood manufacturers are making a very competitive product vis à vis reconstituted products such as fibreboard. The figures indicate the status of the veneer and plywood industry in the two countries which can be attributed to production practices, management techniques and status of research and development that cater for the needs and problems of the industry. To cite an example, it is important to make plywood a competitive product by: i) increasing the veneer recovery or efficient utilisation of raw material from the forest through to plywood manufacture; ii) achieving economic efficiency in veneer and plywood plants; and iii) making plywood a competitive product and improving its market share.

This chapter reviews modelling studies in veneer and plywood manufacturing, specifically: i) areas of veneer conversion and recovery; and ii) modelling veneer and plywood operation. The first part of the chapter reviews studies conducted that have dealt with the effects of material variability in relation to veneer conversion (quantity) and recovery (quality); the second part discusses mathematical models that help improve profitability of running veneer and plywood plant operations.

2.1 Veneer Recovery and Conversion Modelling

Plywood is a pioneer panel product which has undergone the usual stage of research and product development just like any other product. In this process, researchers have explored every aspect of the operation starting from species (Phillips *et al.*,1979; Woodfin, 1973;), peeling characteristics (Lutz, 1964; MacPeak, 1987, Sicad, 1987; Faust and Rice, 1986), veneer drying characteristic (Lutz, 1955; Loehnertz, 1988) gluing (Koch, 1985; Chen and Rice, 1973; Faust and Rice, 1986, 1987), pressing (Wellons *et al.*, 1983), plywood strength properties (Bohlen, 1975; Biblis and Lee, 1987), preservation (Miller and Currier, 1964; Mitchoff and Morrell, 1991) and durability (McLaughlan, 1991; Krahmer *et al.*, 1992) in attempts to improve the quality of the product and profitability of the manufacturing operations. Improvement of rotary lathes and their attachments has also been pursued in order to respond to the need to increase veneer recovery by reducing log spin-out which increases timber consumption and wood cost: for example, i) nosebar configurations were studied to improve veneer quality and reduced spin-out rate which eventually increased veneer recovery (Feihl, 1968; Lutz *et al.*, 1976 and Walser; 1978); ii) chuck designs were investigated to provide needed torque during peeling; and these investigations revealed that chucks with relatively slender spurs transmitted greater torque before spinning out than did chucks with relatively large circumferential surface profiles (Fronczak and Patzer, 1982). They can have a dramatic effect through reducing spin-out rate and attaining smaller log core at minimal cost; and iii) the study and fabrication of powered back-up rolls to reduce spin-out, increased veneer and stud recovery (Fronczak and Loehnertz, 1982; Loehnertz, 1982a, 1982b). The commercial back-up roll model for Boise Cascade Yakima plywood plant has significantly reduced spin-outs in less than a year, while the savings derived from increased veneer recovery have paidback the machine cost. Furthermore, simulation techniques were used in production methods to improve veneer recovery: for example, i) log centering simulation to point out probable losses of veneer if the block was not properly aligned (Foschi, 1976); and ii) veneer clipping simulation models to evaluate different clipping strategies (for grade and for volume) to obtain the needed veneer mix for planned plywood production (Tobin and Bethel, 1969; Funck and Sheffield, 1985; Funck and Babb, 1987). These studies clearly show that the reseachers were trying to solve the most important production issues that continually face plywood manufacturers: i) veneer recovery and conversion from round logs; and ii) accounting for volume losses from the veneer block to the finished product.

The following subsections discuss research studies which focused on log characteristics and other factors with regard to their effect on veneer recovery and conversion.

2.1.1 Source of Timber

Although it is a common knowledge that logs vary in quality and size from stand to stand as a result of different growing conditions, even with the same silvicultural management employed at the same age, the effect of location has not been properly studied and evaluated in relation to veneer recovery and conversion. Philipps *et al.* (1979) studied the veneer yield of southern pine [loblolly (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.)] logs from 5 locations in the Southeast of the United States of America, but, in the analysis of their results, the effect of location was not discussed. The same applies also to the studies conducted on unpruned (Ward *et al.*, 1987) and unpruned (Park, 1987) radiata pine logs in New Zealand. The location or compartment in this case was used in these latter studies only to eliminate the variability factor in predicting veneer yield. However, workers in sawmills and plymills could confirm that there is a great difference in lumber and veneer yields in terms of grade and quantity from logs originating from different locations.

2.1.2 Silvicultural Practices

I. Pruned and Unpruned Logs

Studies of pruned radiata pine logs by Park (1987) and of unpuned logs by Ward *et al.*, (1987) revealed that recovery was clearly related to the type of logs. Park pointed out that veneer conversion depends on the peel index, which is a function of small end diameter (SED) of the blocks. The veneer recovery of grade B and better is a function of clear veneer index which also depends on the size and position of the so called defect-core (a cylinder containing pith, branch stubs, and occlusion scars). Ward discovered that in unpruned logs, total veneer yield recovered is a function of SED squared, ovality, sweep and peeler core size. Branch index (average diameter of the largest single branch in each log quartile) and yield of C grade and better also have a broad association: below a 3 cm branch index there is 80 percent yield of C grade, and above 5 cm there is virtually none. All of these factors are likely to be influenced by the degree and kind of pruning that has been undertaken. The studies did not mention, however, the different average veneer yield from pruned and unpruned logs.

In the United States of America, the effect of pruning coastal Douglas-fir on veneer recovery was also studied in order to promote pruning as a silvicultural tool in young-growth Douglas (Cahill *et al.*, 1988). Pruned logs were shown to recover the same total volume of veneer products as unpruned logs, but recovered more high-grade veneer while recovery of high-grade veneer increased as the diameter of the unpruned core decreased. This type of information can aid managers in assessing how to find the right combination of logs to produce the needed veneer mix for scheduled plywood production.

II. Thinned and Unthinned Stands

The effect of thinning on veneer recovery in second-growth coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) was studied by Fahey (1974). Through analysis of covariance, he determined that there was no statistically significant difference in the grade No. 2 sawmill blocks between thinned and unthinned stands in any of the following tests. The dependent variables were: i) recovery ratio, square feet of veneer (3/8-inch basis) per board foot ii) cubic volume of veneer as a percent of block cubic volume; iii) cubic volume of reject as a percent of block cubic volume; iv) cubic volume of veneer and reject as a percent of block cubic volume, with log small end diameter as the covariate.

2.1.3 Diameter

Diameter breast height (d), merchantable height (h_m) measured from standing southern [loblolly (*Pinus taeda* L.) and slash (*Pinus elliottii* Engelm.)] pines have been studied by Phillips *et al.* (1979), (1980). The diameter squared times merchantable height (d^2h_m) was found to be the most significant factor in predicting grade and total veneer yield.

Fahey (1974) also studied the effect of block diameter on second-growth Douglas-fir stands for the production of veneer, particularly for structural sheathing grades. Log diameter of a grade called No. 3 Sawmill was significantly correlated with the percent of A through C grade veneer. Special Peeler and No. 2 sawmill grade diameters were not correlated with the veneer grades.

In the studies of pruned (Park, 1987) and unpruned (Ward *et al.*, 1987) radiata pine logs, SED of logs was found to be the main factor affecting the total veneer recovered as well as the grade yields produced.

These results indicate that diameter of logs is the main factor contributing to the successful prediction of total veneer and individual grade yields.

2.1.4 Tree Stem

With an increasing tendency to substitute other products for plywood, especially for sheathing with oriented strand board (OSB), plywood manufacturers in the U.S.A. have strategically shifted to producing more specialty plywood which requires B grade or better. In this respect, Clark (1991) examined the impacts of taking several blocks from stems of [loblolly (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.)] to help in designing an experimental tree-grading system that is suited to characterising recovery for more specialty products, requiring a larger proportion of grade B and better veneers. The five tree grade systems evaluated were: i) two grades based primarily on number of clear faces in the first two blocks; ii) two grades based primarily on number of clear faces in the first three blocks; iii) two grades based on size and number of knots and branches in the first two blocks; iv) two grades based primarily on size and number of knots and branches in the first three blocks with up to three 1.5 inch and 2.5-inch knots allowed in the third block; and v) four grades based primarily on grading the first three blocks individually using the size and number of knots and branches in each block. The presence and size of seams, canker, sweep, and crook were also taken into account in each system. This analysis led to the development of tree grades, based on the size and number of knots and branches which correlate better with veneer recovery yields than do tree grades based on number of clear faces. The first three blocks in a tree grading system rather than the first two blocks increased the ability to select trees that might yield a high proportion of grade B and better veneer. As tree size increased, the proportion of veneer in grade A generally increased, the proportion in B remained relatively constant, the proportion in grade C decreased, and the proportion in grade D increased. The study thus gave the opportunity for tree farmers to capitalise on profitable marketing of all the first three blocks in plywood plants, instead of supplying the topmost one to sawmillers at much lower prices. It is also necessary, of course, to characterise the importance of a partly pruned block for veneer production.

These studies reviewed above were conducted with different objectives, but with the same basic intention, making veneer and plywood manufacturing a more profitable operation. The effect of these factors mentioned above on the economic efficiency of the plant was not fully evaluated, since the studies and the results were analysed as is, not used as inputs to linear programming and simulation models emcompassing the three areas of the operation: material resources, production constraints and the markets. Nevetheless, the results of these studies can provide useful information on and insight into how a certain log mix could best supply the needed veneer requirement to produce the scheduled product mix. Thus, it is important to incorporate veneer yield by recovery and conversion in modelling veneer and plywood operations in order to evaluate properly the effect of log resource in relation to production enviroment and the markets for achieving economic efficiency of the operation.

2.2 Modelling in Veneer and Plywood Operations

This section reviews modelling in veneer and plywood operations and other related models where veneer and plywood manufacture plays an important role. Although, modelling in veneer and plywood operations is generally similar, different authors have viewed the operation in different ways and with different emphases based on their experience, needs and problems arising during the process of modelling. Thus, studies reviewed here have different emphases on formulation, and a range of views on how to capture best the situation and make use of the model to respond to needs. Either linear programming (LP) or mathematical simulation has been used in these studies, with the exception of one in which nonlinear integer programming (NLIP) was chosen.

2.2.1 LP Models in Veneer and Plywood

This subsection discusses mainly the veneer and plywood LP and other models, of which veneer and plywood operations are a part. The review focuses on the needs the models have to address or their function and use; model structure and formulation; and their computer implementation.

I. Needs the Models Addressed

A. Log Allocation Model

Generally log allocation models are more concerned with optimising economic gains from timber resources derived from forest stands than with the profitability of wood processing plants such as veneer and plywood operations. But, log allocation models can fairly represent veneer and plywood manufacture, so it is worth reviewing how veneer and plywood manufacturing has been represented in this type of modelling. Use of linear programming for log allocation that includes veneer and plywood operations, was first noted in the work of Pearse and Sydneysmith (1966). Although their model mainly involved outlining a method for allocating logs among several utilisation processes to achieve greater profitability of forest resource, nevertheless, veneer and plywood manufacture was fairly represented as another option, where different log grades could be allocated and processed to gain more profit in an integrated utilisation complex. Veneer recovery grades and conversion factors for different log grades and plywood material usage were used to represent the veneer and plywood operations. This represents an input-output flow of raw materials between intermediate and final products to achieve material balance. In this model, the veneer and plywood operation represented one of the utilisation centres in order to evaluate properly the log allocation policy of timber resource and consumption pattern against other utilisation options (log selling, lumber and chip production). The logs allocated to veneer and plywood plant were based not only on the requirement of the plant but also on the econmomic profitability of the veneer and plywood operation.

Donnelly (1966) probably produced the first log allocation model which considered in detail the veneer and plywood manufacture as an important factor in log allocation for the actual operation. The study was conducted at the Boise Cascade Corporation in the Idaho region to determine the best allocation of logs between sawmills and plymills. Log species was used as a criterion for resource allocation. The structure of the model focused more on the importance of veneer and plywood than the sawmilling operation. The model included: i) veneer recovery by veneer thickness and grades from the different species and layup options for the different products; ii) major machine constraints (lathe, dry and spreader capacities) to represent the production side of the operation; and iii) aggregated market requirement constraints in terms of panel thickness. The sawmill operation was represented by the lumber conversion factors and sawmill headrig capacity instead of overall sawmill capacity. The model was used in annual and monthly planning horizons. At the monthly level, the mill manager was persuaded to produce the product mix forecasted by the LP model. The plant's first monthly profit was approximately US $ 50 000, exceeding the plant's total profits for the previous seven months by 90 percent.

Ramsing (1968) mentioned the importance of a log-to-plywood LP model in determining the product mix from different stands of growing timber not only in the of allocation of available logs. The main emphasis of the study was on veneer to plywood model and product mix determination (see next section B).

Mendoza (1980) also adopted a model structure similar to that presented by Pearse and Sydneysmith, with additional processing capacities (minimum and maximum) for sawmill and plywood, but with the pulpmill excluded in the log allocation model as a second stage decision problem in conjuction with the first one, the stem conversion model. The veneer and plywood operation was used again as a conversion facility option to allocate logs efficiently in a log merchandising operation as part of the forest planning activity.

Mendoza and Bare (1988) used the original allocation model developed by Pearse and Sydneysmith with additional marketing constraints for the lumber products. The main emphasis of this study was to demonstrate the *de novo* programming or soft optimisation of a single and multi-objective LP log allocation model to design an optimal system, rather than to optimise a suboptimal system. The soft optimisation concept or *de novo* formulation works on the assumption that not all the right-hand-side (RHS) values of the constraints are fixed (hard). But some should be rather soft or unknown, and determined only through analysis. The demonstration of the *de novo* formulation focused more on log allocation in relation to lumber manufacturing but not on the veneer and plywood operation.

Bare *et al.* (1989) also demonstrated the *de novo* programming approach in a log allocation model in which a firm is operating one timber sale for both log export customers and domestic processing mills (sawmill, veneer mill and pulpmill). The study dealt with merchandising and allocating logs that had already been crosscut or bucked. The main difference from earlier work of Mendoza and Bare in this study is the unique features of the log classification and allocation method, in which the logs are classified according to log diameter and length, while the four market options can compete directly for certain log sizes. Thus, the importance of the allocation focused on the opportunity to quantify the impact of individual log size in terms of diameter and length. The study revealed that some of the logs that were previously or traditionally allocated to one market, were better allocated to a different market, because it might be profitable to purchase logs intended for the sawmill and buck them to export length for the export customer and chip the remaining portion at the right export price. The authors also recognised and emphasised the application of soft optimisation to veneer and plywood operations, in which log and/or veneer resources are to be optimally designed to meet a set of products ordered by customers.

B. Layup Option and Product Mix Determination Model

Most of the veneer and plywood LP models that have been developed incorporate the choice of layup option to be determined: for example, in Palmer (1979) and Kotak (1976), although neither discussed in detail the relevance of panel layup option to determining the total profitability of veneer and plywood operations. The works of Koenigsberg (1960), Donnelly (1966) and Ramsing (1968) exemplify the relevance of layup option to profitability. The panel layup option matrix is actually the basic core of realistic veneer and plywood LP models. The matrix involves finding the right combination of veneer laminae to be laid-up in prescribed panel construction options with a given set of veneer grades and thicknesses to satisfy other constraints, such as: available veneer (veneer produced from logs to veneer activity or veneer inventory); minimum and maximum volume of the panel grade and thickness; and plywood production machine constraints. Determination of the layup option is synonymous with product mix determination, since the shadow price of the panel product determines the profitability of one product relative to another, and this is also dependent on the optimum layup options selected or on how the specific veneer has been valued in production.

Ramsing (1968) found out that producing only 17 panels, out of the 58 that the firm was actually producing, would result in an increase in profit by over two times that of the actual run, if the firm had followed an LP optimal mix over a 3 week planning horizon. He claimed, moreover, that many product mix determination techniques in this industry lack a computational algorithm like that of the linear programming approach.

C. Production Planning Model

The first veneer and plywood LP model was developed by Bethel and Harell (1957) demonstrating how the usual production problems such as product mix optimisation in relation to machine constraints, together with market and distribution or transportation problems can be addressed with LP modelling. The simplex technique was illustrated step by step to solve the product mix problem.

Kotak (1976) used LP modelling to analyse potential opportunities and produce an annual operating plan for a large plant. The plan of annual operations developed was a result of using parametric techniques in the LP model. Thus, contingency analyses of major assumptions could be analysed. The effect of varying these assumptions was evaluated in terms of dollars as well as in terms of how to accomodate the required changes to the plan. This work was recognised as a leading contender among applications papers in 1976 in a competition sponsored by the Institute of Management Sciences.

Palmer (1971) evaluated the production side of an actual veneer and plywood operation using LP models. He focused on the effect of allocating additional time to the bottleneck machine centre (the dryer) using parametric programming. An increase in net profit of 0.5 percent over the already optimised net annual profit could be realised if an additional 24 hours per week (at no cost) of dryer time could be provided to the normal available dryer time over an annual planning horizon.

Seale *et al.* (1989) implemented an LP modelling technique in two southern pine plywood plants in the U.S.A. to minimise the cost of production for specified mixes of panels in the sales restrictions. They claimed that structures of their model or matrices were able to project mill operating costs and income within 5 percent. The model solution yielded over four times the profit level actually attained by the mill, but the strategy could not be adopted because of real-world restrictions from market forces. They pointed out, however, that the difference between profit maximisation and constrained optimisation can be used to gauge the effectiveness of a sales force over time.

D. Scheduling and Control Model

The use of LP modelling in scheduling and control has been extensively discussed by: Yaptenco and Wylie (1970); and Wellwood (1971). Yaptenco and Wylie explained and demonstrated the quantitative approach to plywood production scheduling through the use of algebraic and difference equations which lead to the creation of vectors and a matrix to form a mathematical model. The model included veneer grade inventories at different stages of the green-end and dry-end of the operation and machine centres (i.e. lathes, dryers, bandsaw, edge gluers, patchers and spreaders). An 8-hour scheduling period was considered for the modelling. Wellwood showed the step by step framework for scheduling, and how LP could help if desired. The study was concerned with achieving an aggregated annual plan through short-term scheduling. The data requirements and how to gather them were fully discussed. A 10-day planning period LP model was constructed and its use was discussed, especially on the importance of the in-plant veneer inventories as a buffer against unpredictable swings in veneer generation. More recently in 1992, a model was developed for Coastal Lumber Company's mill complex in Havana, Florida, which boosted profit by $ 2 million a year (Forest Industries, 1992). The model has been used in all aspects of veneer and plywood operations, including the formulation of a detailed plan for daily scheduling of machine centres.

II. Model Structure and Formulation

Most of the models developed in veneer and plywood production have been structured to accommodate either single-stage or second-stage optimisation. The log allocation model of Pearse and Sydneysmith (1966) is a typical example of single-stage optimisation in which the log supply available for production is optimised along with the other constraints. The models developed by Ramsing (1968); Donnelly (1966) and Palmer (1971) displayed the two-stage optimisation structure, in which the logs and the corresponding veneer outturn from the logs through the layup options are being optimised along with production and aggregate market constraints.

In most of models reviewed, the unit of measure used is different from one activity to another. Logs were measured in units relating to sawn outturn volume (e.g. MBF), veneers in surface area (e.g. MSF in terms of 3/8 inch panel thickness) and panels in number of panels of a certain size (e.g. M-Panels in terms of 3/8' x 4' x 8') or surface area (e.g. MSF in terms of 3/8 inch panel thickness). This heterogeneous mix of measurement units makes the LP formulation and analysis of results hard to trace. This type of formulation is prone to misinterpretation of the results especially in the interpretation of the shadow prices and how they relate to other variables. A straightforward analysis of the LP outputs is impossible to achieve because of these problems.

III. Computer Model Implementation

In most of the models presented, the working model was being developed and implemented on mainframe computers. Data entry procedures and writing programs were part of the normal routine work in developing working models. The power of mainframes in 1957 was probably equal to that of the first PC release in 1983 making it difficult to formulate and accurately solve large realistic models. Harrell and Bethel (1957) cited that a 25 x 50 matrix could be solved on an IBM 701 computer in approximately 30 seconds per iteration. This high-speed computational equipment as they described it, was not readily available within a company, but only at computer centres. Donnelly (1966) discussed the problem of hardware availability, at Boise Cascade where IBM 1410 and 1401 computers were available, but, which were found to be too small to solve the linear programming models in a reasonable amount of time. Thus computer time was leased on an IBM 7094 owned by the Service Bureau Corporation in Palo Alto, California. Most of the models were run only annually for strategic planning and results at the annual level were simply disaggregated to formulate the monthly schedules. Implementing the models in real-time to respond to the needs was not done due to excessive computing cost. Likewise, the parametric programming technique was not widely used to evaluate the effect of one constraint on other.

Two later veneer and plywood LP models (Seale *et al.*, 1989; Spelter, 1990) were implemented on the PC platform with a 8086 CPU, 8087 math co-processor and 640 Kb of RAM. Seale's model consists of three sub-programs: i) the first manages mill data; ii) the second reads the mill data and produces an LP matrix compatible with several microcomputer LP solution packages; and the third reads the output from the LP solution package and produces a management report. The same approach was also adopted by Spelter, using a wordprocessor as text editor and a spreadsheet to produce the data file for LINDO LP packages, while program (READ) was developed to generate reports. Implementation has satisfied the need to produce the required output but implementation in single PC environment would certainly improve the use of the model routinely to respond to the need of real-time decision support tools in veneer and plywood operations. Chapter 5 discusses in detail the desirable features for routine implementation of LP models.

2.2.2 Simulation Models in Veneer and Plywood

Simulation is also used to model veneer and plywood operations, to reflect particularly the production side of the operation. Sampson (1979) argued that simulation techniques can address the random nature of log inputs and machine downtimes, and to model buffer storage space and bottlenecks between processes better than LP. Ward (1987) developed a computer-based simulation model of the manufacturing process. This model was developed using a combination of LP, simple queueing theory, and simulation techniques. In this model part by part analysis is conducted at different stage of the process using different modelling tools. Thus, the effect of one factor on other in different stages of the process could not be properly evaluated. To cite an example, the effect of the log characteristics (e.g. SED, type, etc.) used in the peeling simulation to produce the veneers as an input to run LP programs for determinig layup option could not be properly evaluated. Spelter (1990) also developed a simulation model of a plywood manufacturing process (PLYMAP) to make quick estimates of the economic impact of the particular process changes within a mill. Spelter and Sleet (1989) used that simulation model to investigate the potential reduction in plywood manufacturing costs resulting from improved technology and revealed that a modernised mill could process wood input into the same product output with about 14 percent lower variable costs. Futhermore, 20 to 24 percent in additional cost savings could be realised by replacing medium-diameter (14-inch) blocks with small-diameter (9-inch) blocks and annual output could increase by 13 to 28 percent without adding more lathes, dryers, or presses. The model has three key liminations; i) only one veneer thickness can be specified per run; ii) purchases of outside veneer are not modelled; iii) only one grade and thickness of panel can be laid up per run.

This type of modelling technique analyses the operations part by part rather than on an overall systems approach, in which all factors are taken into account in deriving the solution. This technique could not find an optimal solution from a range of alternatives, but only makes calculations based upon user-entered assumptions.

2.2.3 NLIP in Veneer and Plywood

Non-linear integer programming was also used in veneer and plywood operations to model plywood designs or plywood construction. Atkins *et al.* (1984) developed a model for designing an odd number of veneers within balanced designs. The model evaluated the economic gains in laying up different thickness laminae in a single panel. The objective of the model was to maximize net revenue, while constraints restricted: i) veneer thickness tolerance; ii) plywood thicknesses; iii) log consumption to veneer production; iv) log availability; v) plywood construction alternatives (layup options in terms of thickness not grade); vi) veneer consumption to plywood production; and vii) demand/orderfile. This model generated a solution that reduced wood loss by 79 percent and increased the net revenue by 7 percent. In this model, however, neither the production side nor machine centres constraints were included, while layup options considered only veneer thickness not grades. It should be noted the profitability of the veneer and plywood operation is greatly affected by the grade outturn of the veneers and the rate of the different machines to produce the products.

2.3 Summary

This chapter has reviewed different modelling approaches used in the past for veneer and plywood manufacturing. In areas of veneer recovery and conversion, regression techniques were widely used to investigate the effect of material variability. In most of these studies, the effect of log diameter was thoroughly investigated and revealed that it is the most measurable factor that contributes to veneer conversion and recovery, but the effects of source and type of logs and peeled veneer thickness in conjuction with diameter also needed to be considered. LP, simulation and NLIP have all been used in veneer and plywood plant modelling. LP appears to be the most appropriate modelling technique for best capturing the essence of the operation. Nevertheless, the effects of log resource in relation to production environment and the effects markets on overall profitability of veneer and plywood, have not been fully investigated in LP modelling studies. In most of the models reviewed, production aspects of the operation were given most consideration, apart from log resource and the markets. Chapter 3 discusses how some of the limitations and deficiencies identified in this chapter can be overcome through proper data collection techniques to structure an efficient model for overall decision making in veneer and plywood operations.

Chapter 3

Data Collection and Analysis

In most mathematical model building studies, detailed aspects of data collection are an often neglected topic for discussion. The process of data collection is given less prominence probably because it is always presumed that the data required are already available for modelling. Moreover, modelling in forestry and forest products manufacturing is geared more towards resource management planning than wood utilisation. Resource management planning and modelling usually focuses on the strategic planning level. The data required for that are highly aggregated; they are generally acquired from survey questionnaires and collation from other studies. The strategic planning model is furthermore characterised by: (i) a high degree of risk and uncertainty; (ii) the level of detail in the model structure, which is highly aggregated; (iii) the sources of information, which are both external and internal to the operation; (iv) the breadth of decision making to be addressed; (v) purpose of the model, which is designed for top management use; (vi) the time horizon, which is long and (vii) the objective of modelling or planning, which is generally for resource management (Gunn, E. 1991; Silverside, 1985).

In this particular study, however, Anthony's hierarchy of managerial decisions embracing the strategic planning, tactical planning, and operational control (Hax,

1976) is to be addressed within the one model, if possible. The distinctiveness of the model for use in any strategic, tactical and operational circumstances should be minimal as is explained later in 4.5 and 4.7. The model structure should be very detailed to address effectively the needs for operational control planning, while at the same time it can be used to address strategic and tactical planning in adequate depth. The quality of the detailed data largely determines the model structure, reliability of the outputs and the effectiveness of the model to address the problems. The degree of uncertainty and risk contained in the modelling also, when used for operational control, needs to be low. Thus, the data to be collected and to be used in the modelling should describe the current situation of the plant and eventually should go beyond the point of just addressing current problems.

It is almost always presumed, however, that the data available from production records are the best data with which to start modelling, because the same data are used by managers to make decisions. But the way in which such production data are collected and stored is of great importance, because mathematical modelling transcends the traditional way of making decisions, namely through implementing rules of thumb on which most managers rely. The framework of mathematical models is such that it relies on a systems approach, in which every possible relevant factor is considered in order to try to come up with a comprehensively best solution. Thus, every aspect of the operation to be modelled should be examined closely when taking this approach to determine what sorts of data are needed. In most cases the kinds and quality of data are not available and ways to acquire them are costly (Ramsing, 1968).

This chapter suggests what, where and how processing or manufacturing data appropriate for structuring veneer and plywood LP models should be gathered, to supplement production records and database needed to formulate and implement the models; it also discusses the problems encountered with the approach and how they can be overcome; it describes methods of collecting data effectively; it presents the results; and it briefly points out how the production data could be used to improve the model structure.

3.1 The Veneer and Plywood Plant

The data used in this study were obtained from operations at the Carter Holt Harvey veneer and plywood plant situated in Kinleith Industrial Park, near Tokoroa in the Central North Island of New Zealand, as shown in Figure 3-1. The plant processes pruned and unpruned logs of radiata pine for veneer and plywood manufacture. The plant has an annual output rated capacity of 44 000 cubic metres of plywood. It operates 5 days a week, with 3 shifts/day for the veneer section and 2 shifts/day for plywood manufacturing. The plant employs 120 people altogether, including administrative staff. It produces veneers for export as well as for manufacturing its own plywood. The plywood products are sold on both domestic and export markets. The main export markets for plywood are Australia, Hongkong and Taiwan, while veneers are sent mostly to North America and Japan.

The plant is strategically located to procure logs from Kinleith Forests, Tasman Forestry and New Zealand Forest Corporation forests, also shown in Figure 3-1. The plant, however, faces competition for raw materials from neighbouring sawmills. On the other hand, this competition could be exploited positively, as its represents an opportunity to trade logs that suit one plant but not the other.

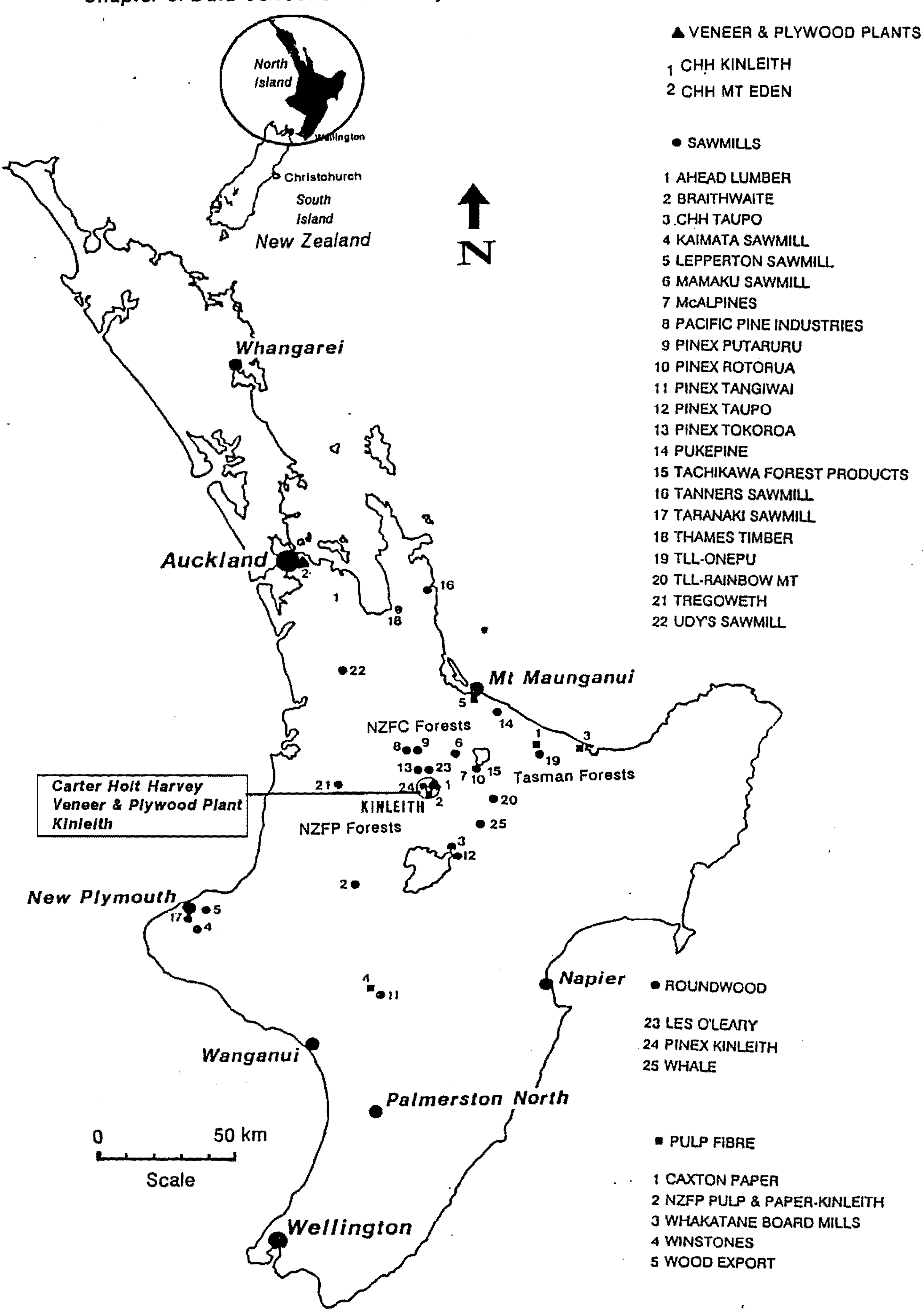


Figure 3-1. Location Map of CHH Veneer and Plywood Plant

3.2 Data Gathering Strategy

An attempt was made first of all to gather data for this study from a written survey of managers' knowledge, (see Appendix A), but the questionnaire findings revealed that the plant did not record enough processing data, and some information that is recorded is inappropriate for formulating the desired linear programming model in the detail required to tackle the problem of decision making in veneer and plywood operations as set out in the objectives of this study. In this regard, this plant was no exception to the general situation as described in previous studies (e.g. Bethel and Harrell, 1957). Data collation of production records was undertaken, therefore, to obtain recorded data but, even when all were gathered, still the amount was insufficient to build a good mathematical model. Hence, in order to address the situation properly and formulate effective models, veneer recovery and time and motion studies were conducted to supplement the production records.

3.3 Veneer and Plywood Manufacturing Process

In order to grasp fully the decision making needed for veneer and plywood operations, the importance of data collection and the things to be modelled, it is imperative that the manufacturing processes involved should be fully defined and clarified. In this section, the machine centres are presented together with the technical aspects of the processes involved. There are variations in operating practices from mill to mill depending on plant machine layout and management preference for practices or operations suitable specifically to individual production situations. The processes to be discussed here, nevertheless, are basic processes in veneer and plywood manufacturing and practised in the veneer and plywood plant studied here.

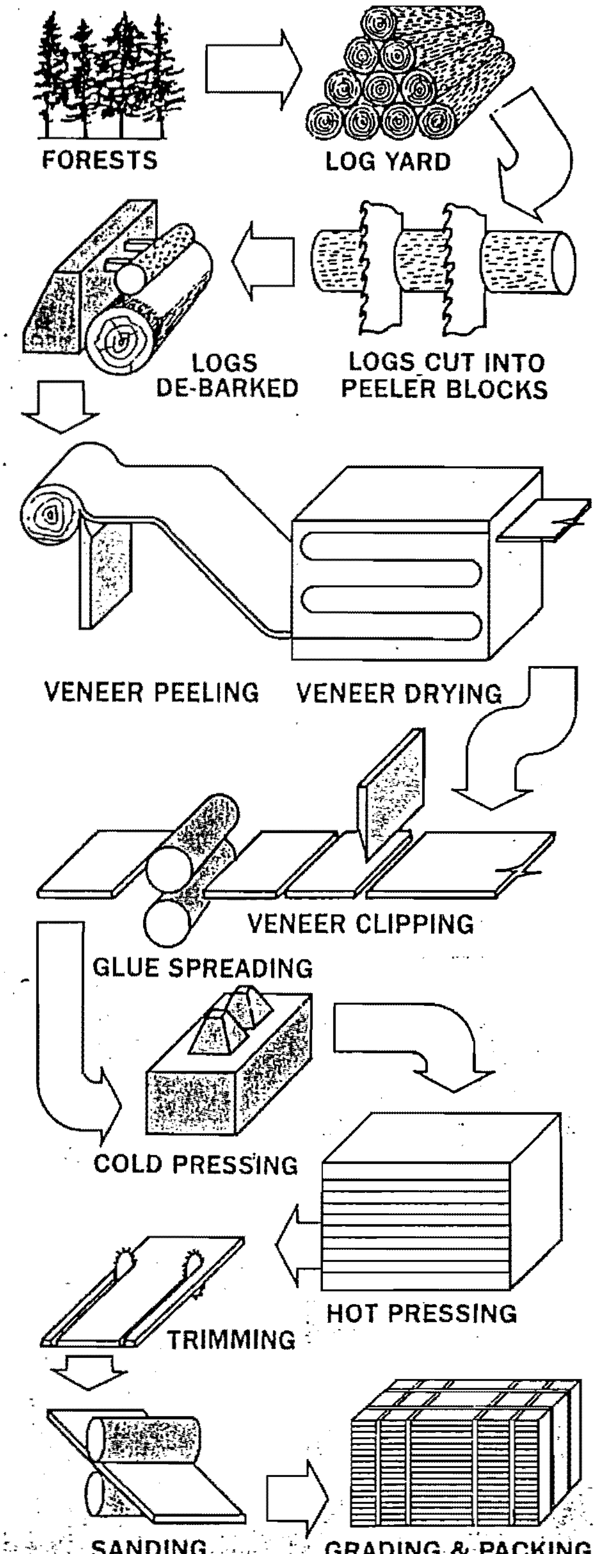
The flowchart of veneer and plywood production and layout for this plant are shown in Figures 3-2.1 and 3-2.2.

3.3.1 Log Handling, Bucking and Debarking

Log handling, in this plant, involves a crane that grips one end of log from the log deck and feeds it on to the chained conveyor belt. The logs are cut into peelable blocks in lengths of 2.5 m by a circular cutoff saw positioned in the middle of the chained conveyor. The blocks are debarked at the end of the conveyor by a ring-type debarker. Debarking reduces nicks and wear on the lathe knife and nosebar. The productivity rate of this machine centre depends on the speed of the machines and the skill of the operator. These machines are operated by a single operator in this plant.

3.3.2 Peeling

Peeling is converting the blocks or logs into thin sheets of veneer by a rotary lathe. It could be best described as simply like unrolling a toilet paper. In most plants, the lathe throughput exceeds dry end capacities, and, thus, lathes are not run throughout the day. However, in this plant, the machine layout was designed for a continuous process; thus, the lathe is run most of the time the plant is operating. The debarked blocks are charged to the lathe by a lathe charger to maximise recovery of full-width veneer. In most modern plants, the lathe is equipped with a X-Y charger that determines how the blocks should be mounted to the lathe chucks in order to achieve greater veneer recovery. When peeling starts, the blocks are pre-rounded (in other plants, blocks are pre-rounded by a different lathe); they are turned several times with the nosebar open to remove larger protrusions such as stubs and butt flutes. After an initial roundup, the trashgate is closed, and the initial portion of veneer ribbon moves



Source: Fletcher Wood Panels Brochure

Figure 3-2.1. Flowchart of Veneer and Plywood Production.

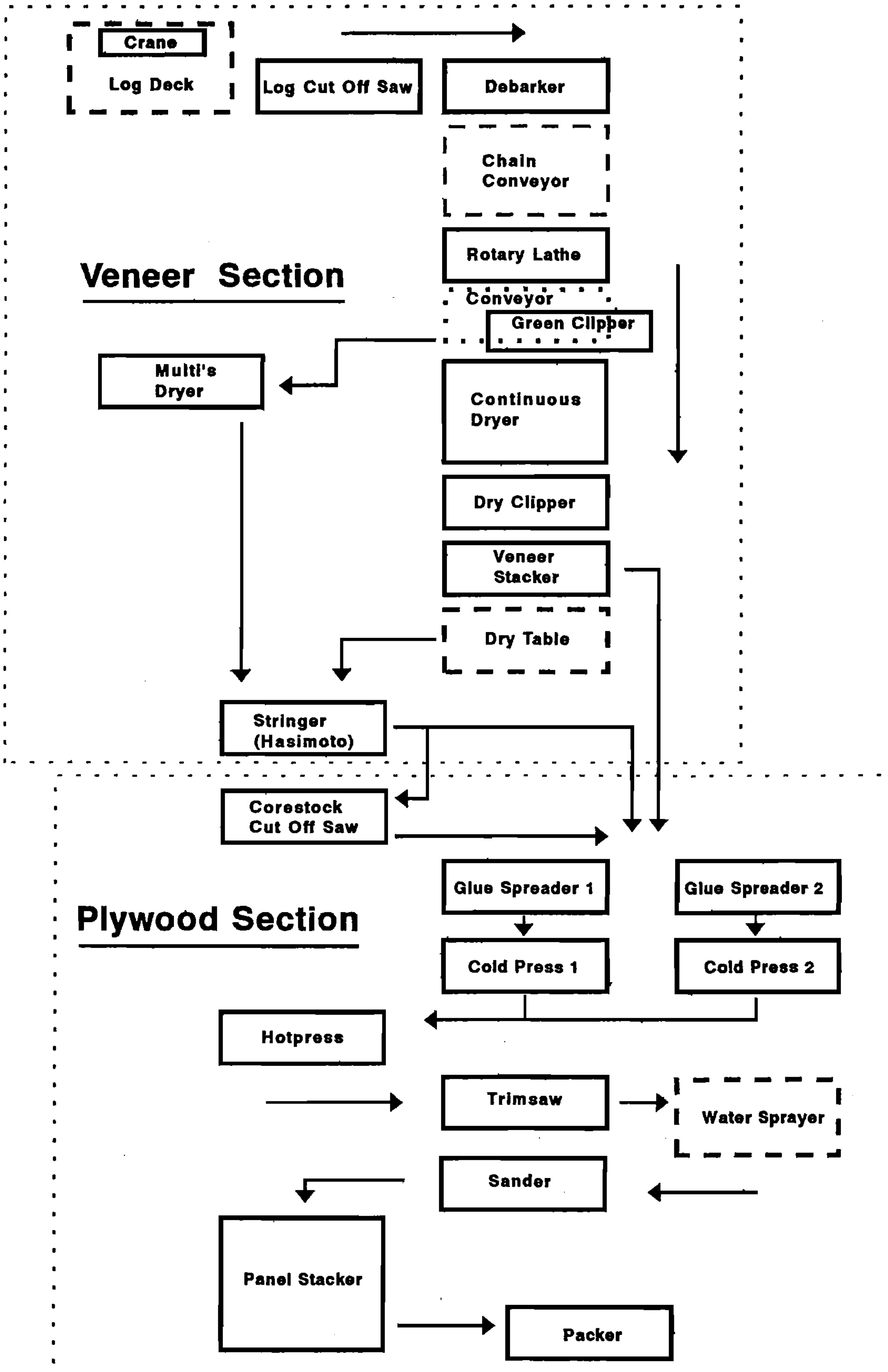


Figure 3-2.2. CHH Veneer and Plywood Plant Layout

down a conveyor to be green clipped and the rest of the veneer ribbon is fed to the dryer.

3.3.3 Green Clipping

Green clipping in this plant is only for roundup veneer to recover fishtails and multiples (random widths) as clear multi's and multi's grade. The most common green clipping practice is done to produce veneer of standard size sheets, green stacked prior to drying them.

3.3.4 Veneer Drying

The veneer ribbon is dried in the continuous dryer in this plant. Veneer drying is necessary to prevent the glue from overpenetrating the wood known as bleed-through and to avoid steam-induced blows in the hot press that caused delamination. The type of dryer determines the basic drying time of veneers for each dryer. Drying time is a function of the dryer temperature, forced air velocity, veneer thickness, wood specific gravity, initial moisture (MC) and target final moisture content MC. The hourly dryer capacity is based upon dryer size, drying time, and operational downtime. In most mills, the dryer is the bottleneck in the production and this plant is probably not an exception.

3.3.5 Dry Clipping

Dry clipping in this plant is to remove defects and produce veneer of a standard size. Recovery at the clipper depends on whether the objective is to clip for volume (for unpruned logs) or grade (for pruned logs). If clipping is for grade, the resulting amount of waste (hog fuel) is greater, and the proportion of full-width sheets in the mix declines. Veneer grading is also done at this stage by the grader-clipper operator who also operates the veneer stacker.

3.3.6 Veneer Stacking

Generally, full sheets are stacked automatically by grade, while random widths and fishtails are pulled from the dry table and stacked manually in the bins. Some mills have also installed stackers for random widths. Green veneer stacking predominates in plywood mills nowadays, but not in this plant where, instead it is done after drying, as presented earlier. Elements of an automatic green stacking system include a sheet diverter, a veneer moisture meter (if heart and sap veneers are segregated), and a mechanical or vacuum sheet-handling device that places sheets into bins. The rate of veneer production in the case of the green stacker is normally greater than the ability to dry the veneer sheets in conventional dryers; hence, stacked veneer is placed in inventory until drying is available. However, in this plant the dry stacked veneer is held as inventory for a period of 2 days or so to allow for cooling and for moisture to equalize within sheets until needed in prebooking (turning up the face and back veneers to ensure correctness of tight-side and loose-side in the layup).

3.3.7 Veneer Stringing

Veneer stringing is done on half- and random-width veneer sheets by unitising and recutting into standard full-width sheets in order to improve plywood quality and facilitate layup automation. Incoming strips are aligned and passed over an anvil where the leading edge is clipped to assure that each strip will fit tightly against the preceding strip. Strands of hot-melt adhesive are put on the veneer over which threads are placed. Immediately the two are pressed by a cooling roller. The trailing edge of the strip is clipped to create a surface that will match that of the next strip. Unitised sheets are then sawn in half to produce a 1.2 m x 1.2 m corestock. The rate of stringing depends on veneer grades (clear multi's and multi's) and veneer width.

3.3.8 Panel Layup

Panel layup consists of applying adhesive to individual veneer sheets and stacking them in the desired panel construction based on the layup options. The glue spreader is used to apply adhesive on corestock which is passed through a core feeder. A pair of glue-coated rollers applied the adhesive on to both sides of the passing sheet. At the outfeed end of the spreader, two workers are positioned to place the crossbands, face and back veneers alternately on to the glue-coated sheets. The grain orientation of the veneers should be perpendicular to each other and exposed side of face and back veneers should be on the tight-side to prevent bleed-through. For this reason, prebooking is necessary. Thin-and-thick veneer (veneer thickness variation caused in peeling that produces wavy veneer) as manifested by uneven glue spread can be easily identified and discarded in this operation. Thin-and-thick veneer causes delamination and leads to rejects after hot pressing.

3.3.9 Pressing

Pressing must be done on freshly assembled panels to prevent the moisture from being absorbed into the wood, a phenomenon known as dry-up. First, the panels are cold pressed to consolidate them and extend assembly times. This also facilitates handling and loading individual panels into the hot press. Pressure in the hot pressing brings the opposing veneer surfaces into close contact, while the heat cures the adhesive. The wood is compressed somewhat, some of it recovers, but a part is permanent. Compression loss can be minimised by incrementally reducing the initial pressure during the press cycle and by watering panels which is done in the plant after leaving the press. The panels are usually stacked and set aside to allow the adhesive to cure properly from the residual heat in the stack.

3.3.10 Trimming

The cool panels are sent to trimming saws that cut the panels into their final size.

3.3.11 Sanding

The trimmed panels are first patched with a cellulose base putty to fill gaps and improve panel grades prior to sanding. Depending upon the panel grades, the panels are full or touch sanded. Speciality panels are usually sanded on both sides.

3.3.12 Grading and Packing

Immediately after sanding, the panels are graded and conveyed to the stacker. The falldown yield from the target panel grade can be determined and recorded at this stage.

3.4 Veneer Recovery Study

Veneer recovery ratio (VRR) defined by Phillips (1980) as the cubic metres of dry untrimmed veneer recovered per cubic metre of log input is a good index of recovery efficiency; such figures represent vitally important data for understanding any veneer and plywood operation. With these data, production managers make decisions on what sort of logs to procure or buy in order to feed the operations to gain more profit. The current practice of recording veneer recovery in this particular plant and in many others in New Zealand or elsewhere, is based on the aggregate volume of logs being input, rather than on individual logs or log size classes (e. g. small end diameter (SED) criteria). Log procurement policy is based on this aggregate system and is often accompanied by the belief that logs producing better quality veneers and which have high recoveries, are the best to procure or buy. But this approach makes it impossible to pinpoint the log diameter classes and other characteristics which lead to good recovery. Managers, however, seem satisfied on how the current system works at present, since: (i) the buying system of logs in New Zealand is done only by volume of the logs rather than by the combination of volume and log diameter class; (ii) managers do not have a tool to quantify how much benefit accrues if the system of diameter class recovery is adapted so that it goes beyond just the purpose of pinpointing logs according to their potential for producing quality veneers; (iii) the process of data collection is tedious and costly for more discerning types of data, and middle managers feel unable to justify the additional expense of such refinement. The present aggregate system of recording recovery is far better, however, than that used by sawmillers at present (clears or clear lumbers are assessed as percentages of the total sawn timber turned out as clears rather than on conversion from the round log (Park, 1992)). But the present processing of data did not meet criteria necessary for this study to address its objectives properly. It was therefore crucial to invoke a system of getting the right data while, at the same time, disrupting the production operation as little as possible. Hence, the veneer recovery study to determine, i) the veneer recovery ratio (VRR) and veneer grade recovery factor (VGRF), and ii) amount of dry untrimmed veneer grade recovered per cubic metre of block / log input, was conducted to demonstrate its feasibility under normal production operating conditions.

3.4.1 Objectives of the Veneer Recovery Study

The objectives of this veneer recovery study were:

1. to establish benchmarks for VRR and VGRF by source, log type, small end diameter class and veneer peel thickness, to be used as coefficients in the linear programming model;
2. to demonstrate the methodology of veneer recovery study by quantity and quality (veneer grades) and by individual blocks or logs, without disturbing the normal operation of the plant;
3. to develop regressions for predicting yield of VRR and VGRF by log source, log type (pruned and unpruned) and veneer thickness, if possible.

3.4.2 Materials and Methods

I. Materials

The main suppliers of logs and the log types available were identified. There were thirteen log classes (log source and type) that the plant was processing at the time of data collection planning as shown in Table 3-1. Of these thirteen log classes, only six were studied because: (i) they were the main logs being processed in the plant at the time; (ii) of manpower constraints; and (iii) of managerial reluctance to conduct this type of veneer recovery study, due to its high cost and possible disruption of the production operation. The specifications for the individual log types studied are presented in detail in Appendix B. This study, of course, did not aim to establish VRR and VGRF for radiata pine generally, since that is another research project in its own right. But the methodology that can be applied is sufficiently general.

Table 3-1. Logs processed in Carter Holt Harvey Plywood Plant Tokoroa

Code Name	Colour Marking	Company	Origin	Status
KH	Black	CHH	Koweka	
KP	Black	CHH	Koweka	
MP	Black	CHH	Mohaka	Studied
PP	Red	NZFP	Timberlands	Studied
UP	Red	NZFP	Timberlands	Studied
CB	Blue	NZFC	Mohaka	Studied
TPB	Green	Tasman	Matahina	Studied
T	Red	PF Olsen	Taumaranui	
GP	Black	OJI-Sankaku	Manawatu - (Gwavas)	
GM	Black	OJI-Sankaku	Manawatu - (Gwavas)	
MH	Black	NZFC	Mohaka	
RP	Black	CHH	Rukomoana	Studied
RH	Black	CHH	Rukomoana	

Note:
CHH - Carter Holt Harvey Forests
NZFP - New Zealand Forest Products
NZFC - New Zealand Forest Corporation
Tasman - Tasman Forestry Limited

II. Methods

A. Log Preparation

An ideal procedure for selecting logs in the log yard by source, type, diameter class with ideal numbers of replicates prior to peeling, as outlined in the study proposal submitted to plant management, could not be made to work on two occasions due to manpower and equipment constraints. The first recovery study was conducted in aggregates of 3 logs to represent the diameter class ranges because of this handicap. In the second study, the resources to conduct the study improved through providing personnel capable of handling the demands of the job in terms of skill and stressfulness. Timely cooperation from the workers is badly needed in order to conduct this kind of study successfully. Improper recording of data and reluctance to do small errands will ruin a whole day's study. The approach, moreover, was completely new and quite radical compared to what has been practised, and so it was no surprise that difficulties were encountered. The log selection and markings were done in the log yard as shown in Figure 3-3.1. The diameter measurements [small end diameter (SED), large end diameter (LED)] were done in the log yard. The log characteristics recorded for the veneer recovery studies were: (i) source, as shown in Table 3-1.; (ii) SED class range (350 to 390 mm, 400 to 450 mm, 460 to 500 mm and 510 to 620 mm) and (iii) veneer peel thickness (2.5 and 3.0 mm). As the logs were bucked and debarked, the SED and LED measurements for the new blocks were taken, using a carpenter's steel tape in the running conveyor. The blocks were spray painted with different colours to identify them properly in subsequent processes, as shown in Figure 3-3.2. The same colour used in marking the

Figure 3-3.1. Selected Logs by Source, Type and SED Class.

Figure 3-3.2. Debarked and Colour Coded Blocks Ready for Peeling.

logs and blocks was retained for the veneer colour coding. The sample size for each category of logs increased considerably in the second study. The methodology did not interfere much with the operation of the plant but it was difficult to find and complete 3 log replicates to represent each diameter class category, since the time between selecting the logs and peeling the first marked block was short while there was also a limited number of logs available in stock in the log deck near the crane.

B. Colour Coding Technique

The colour coding technique used to identify veneer peeled from an individual block in recovery studies and in this study as well, was first described by Lane (1971). The method is widely used in veneer and plywood plants of the West Coast and Southwest of the United States of America (Woodfin, 1973). It is an effective technique in any veneer recovery study under normal production conditions. Aerosols of different colours were used but not, however, the six colour coding spray nozzles apparatus described by Lane. Instead, an eight colour coding system was employed here.

As the block was peeled in the lathe under normal production conditions, green veneers were spray-painted along the edges with unique colour codes, also shown in Figure 3-3.3. The process produced a continuous stripe of colour on all veneers from each block (Figure 3-3.4). The colour coded roundup from each block as clipped in the green clipper and multiples (random-width veneer strips) and fishtails (veneers of less-than-full-block length which are later cut in half lengths for use as corestock) were recorded (Figure 3-3.5). The remaining continuous ribbons of veneer were fed into the

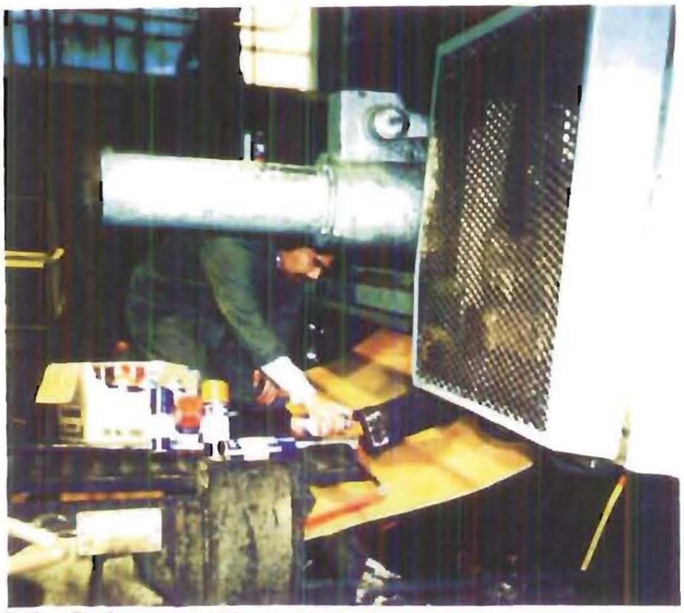


Figure 3-3.3. Colour Coding of Veneer by Edge Spray Painting.

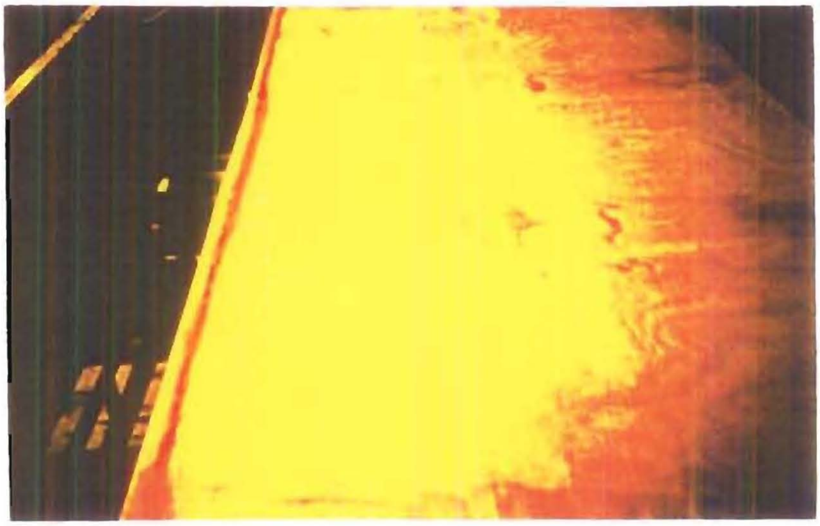


Figure 3-3.4. The Colour Coded Veneer Ribbon.

Figure 3-3.5. Sorting and Grading of Green Multiples and Fishtails.

continuous dryer as part of the normal operation. The dried full sheets were then tallied according to colour codes and veneer grades, (A, B, Cp, C, and D) as they were being dry clipped and graded by the grader-clipper operator. The descriptions of the veneer grade are listed in Table 3-2. The in-house grading rules are much tighter than the NZ specification call for. Dry multiples and dry fishtails were collected on the dry table and placed in bins for further sorting and grading. The multiples and fishtails were collectively categorised as Multi's in this study. The veneers were recorded according to veneer quality and quantity from each block. The veneer measurement was done in terms of 1/4, 1/2, 3/4 and whole of a full sheet measuring 1.265 x 2.535 m. Grading and measuring of dry multiples and fishtails are shown in Figures 3-3.6 and 3-3.7.

Veneer log cores ranged from 178 to 183 mm in diameter and averaged 180 mm. Average core diameter was the same for all block size classes in the study.

Table 3-2. Glossary of Veneer Grades for Radiata Pine

Veneer Grade	General and Specific Descriptions of Allowed Defects
A	Clear veneers with minor filled splits.
	* Splits less than 1.5 mm wide and 300 mm long and or 3.0 mm wide and 150 mm long.
	* No resin streaks or sapstain.
	* No torn grain or sanding defects.
B	Solid face with small intergrown knots and minor filled splits
	* Splits up to 3.0 mm wide and 300 mm long
	* Minor filled defects including stem cone holes and intergrown knots up to 20 mm measured across the grain.
	* Maximum of 2 knots per sheet.
	* Slightly torn grain allowed.
	* Minor resin streaks and sapstain allowed.
Cp	Solid face with filled defects
	* Filled splits up to 10 mm wide, 600 mm long tapering to a point.
	* Filled bark encased knots, 40 mm across the grain.
	* Intergrown knots or knotholes sheet.
	* Minor torn grain and sanding defects.
	* Resin streaks and sapstain allowed.
C	Open defects on the face
	* Knotholes and open defects up to 40 mm across the grain.
	* Unfilled splits up to 10 mm tapering to a point half way along the length of the sheet.
	* Combination of defects - total width of defects in any 300 mm band across the sheet not to exceed 35 % of the sheet width.
D	Open defects on the face.
	* Knots and open defects not exceeding 70 mm across the grain.
	* Intergrown knots up to 70 mm across the grain.
	* Open splits up to 10 mm half the length of a sheet. One only open split up to 25 mm length not restricted.
	* Torn grain, sapstain, resin streaks are allowable.
	* Combination of defects equal to total width of defects on any 300 mm band across the sheet is not to exceed 50 % of the sheet width.

Source: Carter Holt Harvey Plywood Tokoroa Grading Rules.

Figure 3-3.6. Grading and Measuring of Dried Multi Veneers

Figure 3-3.7. Measuring the Dried Fishtails.

C. Yield Prediction using Regression Technique

A multiple linear regression technique was used to establish VRR prediction equations for the pruned and unpruned logs in terms of SED and veneer thickness for this particular veneer and plywood plant. Results indicated that there is a statistically significant though still relatively weak effect of SED^2 on VRR for pruned and unpruned logs (Equation 3.1). Although the overall fit was significant at the 0.01 percent level , precision was not outstanding: the coefficient of variation was $\pm$ 12.5 percent and residuals were within $\pm$ 15 percent of prediction. Examination of residuals showed virtually no bias in prediction, however.

$$VRR = 0.4859 + 0.00004617 * SED^2 + 0.2085 * TPB + 0.0040387 * PP - 0.005256 SED^2 * TPB + 0.0005482 * SED^2 * PP \quad (3.1)$$

Where;

VRR = arcsine transformed proportion of veneer recovered.

SED is small end diameter of block in centimetres.

TPB and PP are dummy variables representing certain log sources.

SED^2 and veneer thickness were also found to be significant for VRR predictions for pruned logs only (Equation 3.2). The fit was significant at the 0.05 percent level, a reasonable level of precision: the coefficient of variation was 12.9 percent and residuals were within $\pm$ 15 percent of prediction. Residuals showed no bias in prediction.

$$VRR = 0.249617 + 0.129617*TPB + 0.000084418*SED^2 + 0.065928*Thk - 0.0000850081*SED^2*TPB \quad (3.2)$$

Where;

Thk is veneer thicknesses (2.5 mm and 3.0 mm)

For unpruned logs, SED^2 is significant in explaining VRR (Equation 3.3). Log type, however, did not appear to have a significant effect on VRR for unpruned logs. The fit was significant at 0.01 percent, a reasonable level of precision, the coefficient of variation was 11.5 percent and residuals were within ± 15 percent of prediction. Residuals showed no bias in prediction.

$$VRR = 0.536013 + 0.000030799*SED^2 \quad (3.3)$$

Trends and relationships of VGRF in veneer grade grouping and individual veneer grade by log source, log type, SED and veneer thickness as well as VRR, log core ratio and hog fuel ratio by log source, log type, SED and veneer thickness were also analysed through simple linear regression. The results are shown in Figure 3-4-1.i to Figure 3-4-9.

3.4.3 Implication of the Results in LP Modelling

The main benefit and usefulness of the VGRF by veneer grade, log source, log type, SED class and veneer thickness from the results of this study, are the capability to construct a detailed structure of log variables and log resource constraints in the LP model. This method of conducting a recovery study by log source, log type, diameter class range and veneer thickness enhances the efficacy of the model to respond to broad and detailed aspects of decision making starting from: i) strategic log procurement, in combination with the soft optimisation to design an optimal system (the log procurement strategy can become more aggressive by buying the right logs at a premium and discarding the undesirable logs to maximise profitability, rather than optimising material recovery); ii) tactical allocation of acquired logs by source, type and SED class to be processed in the right veneer thickness and quantity to manufacture the product mix and selling the undesirable logs; and iii) scheduling the right proportion of log types to produce the veneer requirement of the product mix for the market during a fortnightly planning horizon. These are just a few examples of how these recovery results could be of great assistance in operational planning. An in depth analysis on how the recovery study results can contribute to profitability and improvement in veneer and plywood operation decision making will be discussed in Chapters 4, 5, and 6.

3.4.4 Analysis of Results

With technological improvement in the lathe and peeling, the VRR and VGRF of these logs can be expected to improve in the near future. But the relativities with respect to SED, log type and veneer grade yield would likely be the same. As the log size or block size increased, the proportion of veneer in grade A generally increased, the proportion in grade B remained relatively constant, the proportion in grade Cp increased, the proportion in grade C decreased, and the proportion in grade D increased for radiata pine logs (Figure 3-4-1.i.D). The same trend was found out by Clark (1991) on Douglas fir pruned logs. The SED of the blocks \ logs being studied ranged from 350 mm to 620 mm for both pruned and unpruned logs. The interpreta-

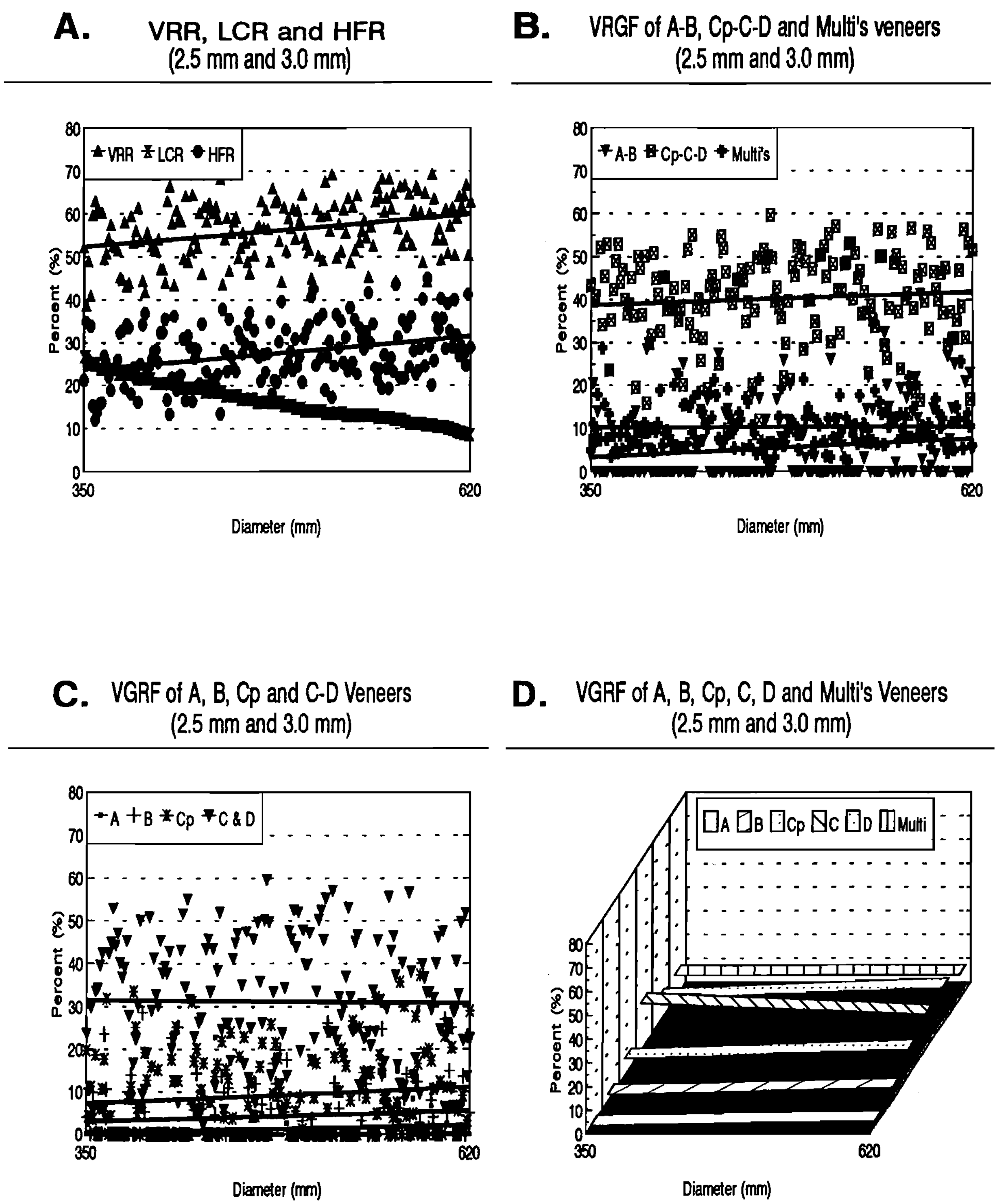


Figure 3-4-1.i. Veneer recovery of pruned and unpruned Pinus radiata logs.

tion of these results is highly dependent on pricing of logs, veneer outturn grades, and production assumptions (Fahey, 1974) which will be discussed in a later chapter. The veneer recovery study in this chapter focuses purely on the trends of VRR and VGRF and how they relate to the deviation of technical coefficients.

I. Pruned and Unpruned Radiata Pine Logs

The VRR of radiata pine logs (pruned and unpruned) lies between 39 - 69 percent, while the average VRR was 56 percent in this study. As the SED of the blocks increases; (i) log core ratio (LCR) decreases and hog fuel (waste) ratio (HFR) increases (Figure 3-4-1.i.A); (ii) multi's slightly increase, A & B veneer grouping increases and Cp-C-D veneer grouping VGRF decreases (Figure 3-4-1.i.B); (iii) grades A, B, Cp and D increase while grade C decreases (Figure 3-4-1.i.D). The VRR and VGRF of the different veneer grades and veneer grade groupings in 3.0 mm veneer thickness are higher than 2.5 mm veneer (Figure 3-4-1.ii).

II. Pruned Logs

In pruned logs, the VRR is slightly lower compared to the VRR of unpruned logs as shown in Figure 3-4-2.i.A and Figure 3-4-7.i.A. The clipping pattern of pruned logs is geared explicitly towards producing more of grades A, B and Cp, and consequently more strips of veneer end up as multiples and hog fuel (waste) (Figure 3-4-2.i.A). Pruned logs are peeled to produce A and B grade face veneers. As the block SED increases, grades A, C and multi's increase, grades B and D decrease, and grade Cp remains constant and grade D decreases (Figure 3-4-2.i.C and D). The VRR of 3.0 mm veneer (Figure 3-4-

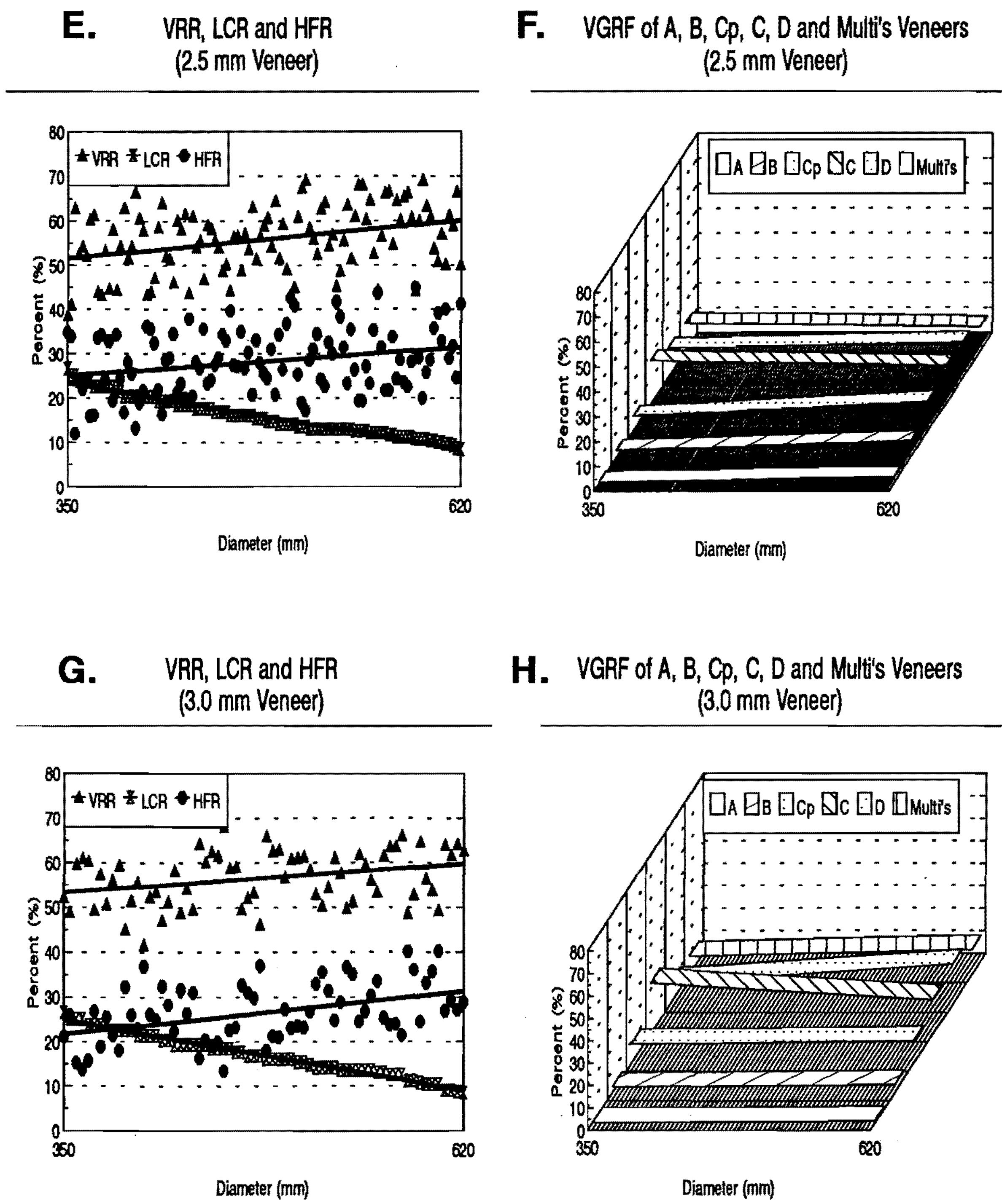
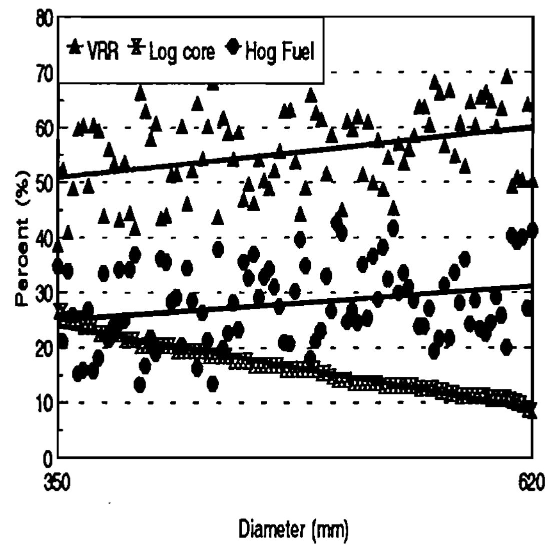
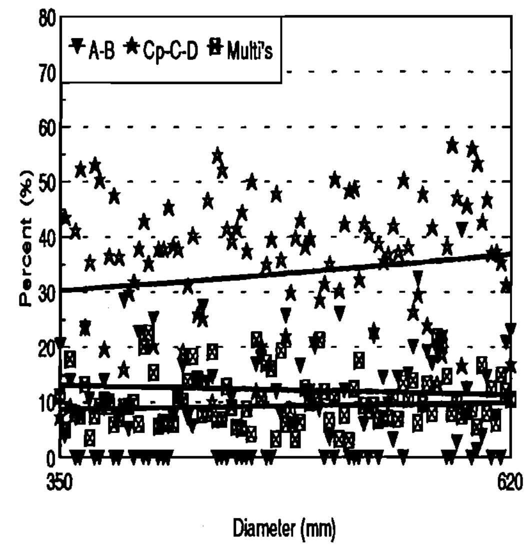


Figure 3-4-1.ii. Veneer recovery of pruned and unpruned Pinus radiata logs.

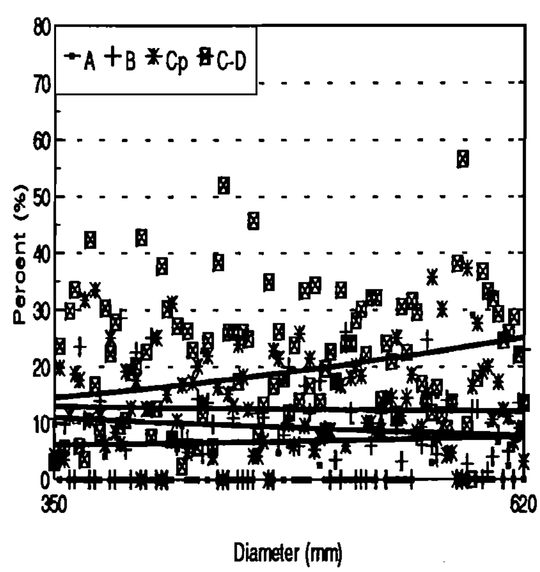
A. VRR, LCR and HFR (2.5 mm and 3.0 mm)



B. VGRF of A-B, Cp-C-D and Multi's Veneers (2.5 mm and 3.0 mm)



C. VGRF of A, B, Cp, and C-D Veneers (2.5 mm and 3.0 mm)



D. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm and 3.0 mm)

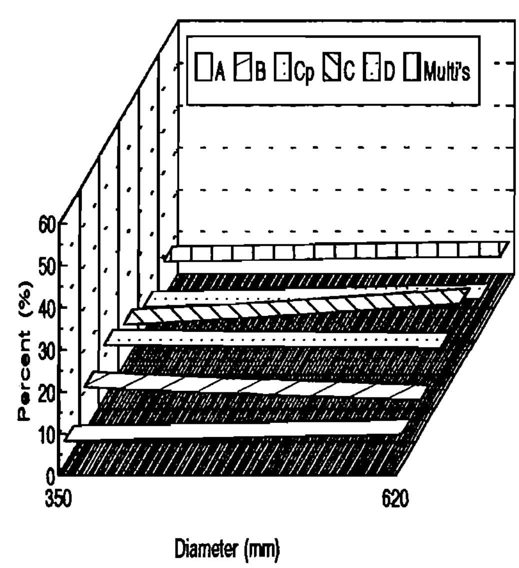


Figure 3-4-2.i. Veneer recovery of pruned Pinus radiata logs.

2.ii.G) is higher than 2.5 mm veneer (Figure 3-4-2.ii.E) for pruned logs. In 2.5 mm veneer, however, grade Cp and C increase (Figure 3-4-2.ii.F) while 3.0 mm veneer grade Cp decreases and grade C increases (Figure 3-4-2.ii.H) as the block SED increases.

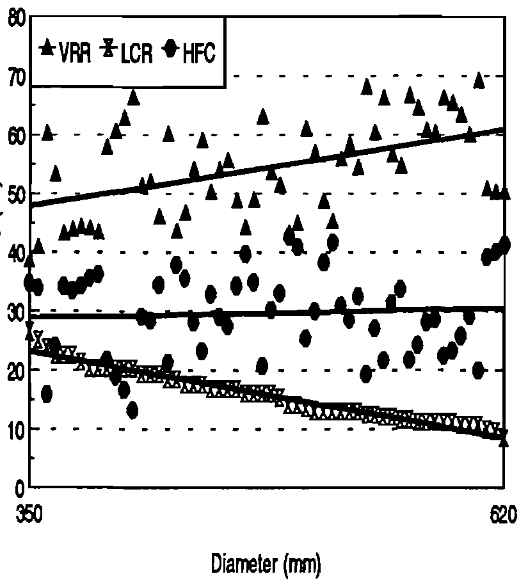
MP logs were studied for only the 2.5 mm veneer recovery and in aggregates of 3 logs or 6 blocks to represent each SED class, the procedure used in the first recovery trial which was restricted due to manpower constraints. With these logs, the hog fuel (waste) ratio tends to decrease as the SED of blocks increases. The A - B VGRF was lowest among the 4 pruned logs. These relationships are shown in Figure 3-4-3.

In PP logs, as the block SED increases, A, Cp and D veneers increase, C decreases, while B remains constant. However, in 3.0 mm veneer VGRF of B tends to increase. The VRR in 3.0 mm veneer is again higher than that for 2.5 mm veneer. These results are shown in Figure 3-4-4.

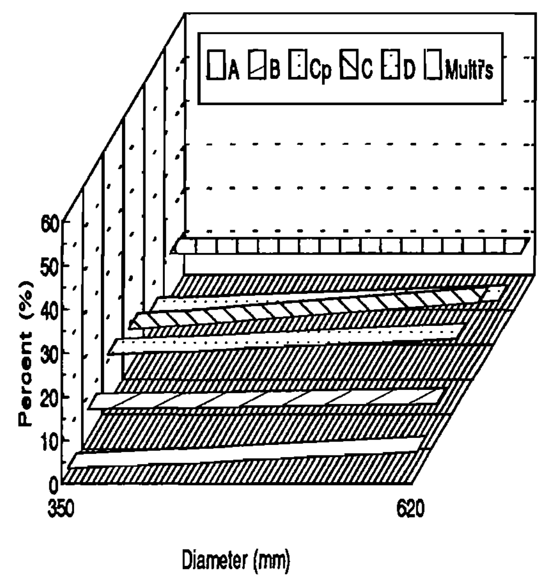
RP logs were studied only in 3.0 mm veneer. The VRR is the highest among the four logs studied (Figure 3-4-5). As block SED increases, A remains constant, B, Cp and D decrease,and C and Multi's increase.

TPB logs are pruned butt logs and these logs have different taper from the rest of the four pruned logs studied. VRR of these logs remains constant as the block SED increases. In separate analysis by veneer thickness, the VRR in both thicknesses tend to decrease as block SED increases. These results are shown in Figure 3-4-6. This trend could be attributed to the taper of the logs and degree of flutes and creases present in these logs.

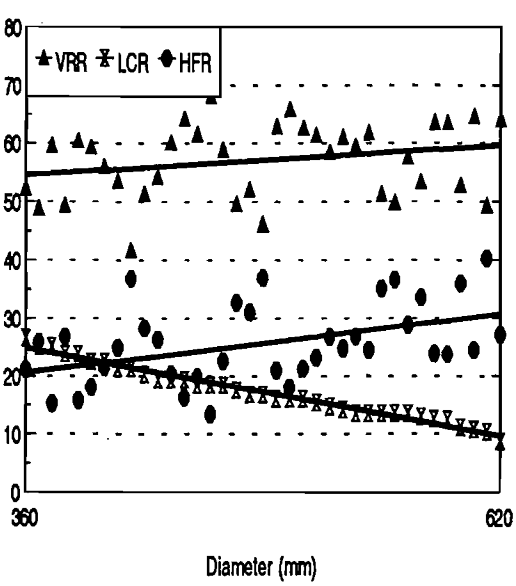
E. VRR, LCR and HFR (2.5 mm Veneer)



F. VGRF of A,B,Cp,C,D and Multi's Veneers (2.5 mm Veneer)



G. VRR, LCR and HFR (3.0 mm Veneer)



H. VGRF of A,B,Cp,C,D and Multi's Veneers (3.0 mm Veneer)

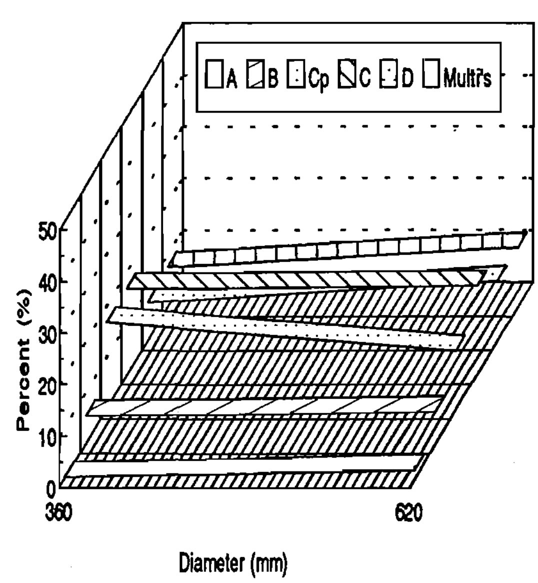
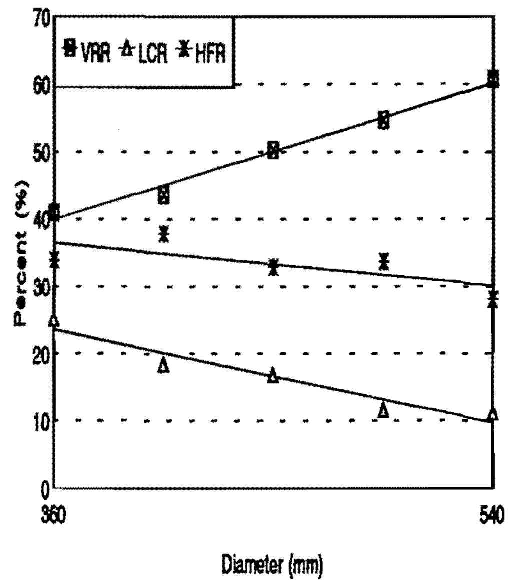
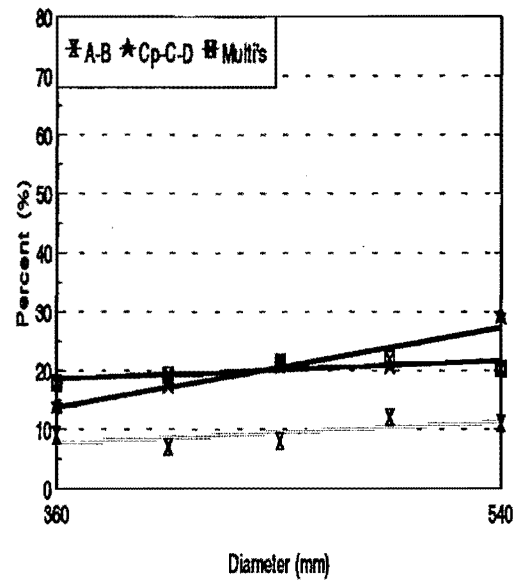


Figure 3-4-2.ii. Veneer recovery of pruned Pinus radiata logs.

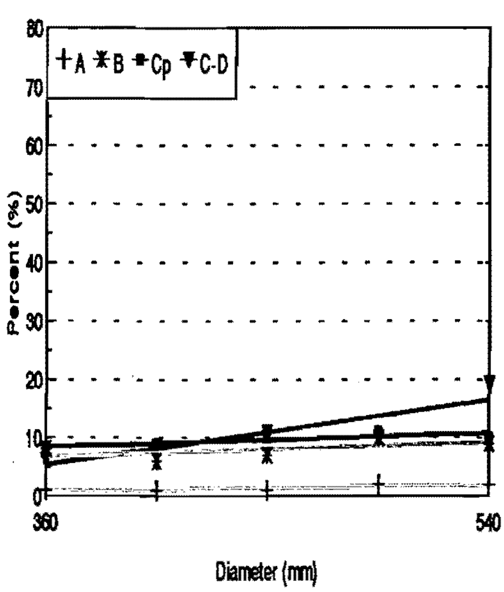
A. VRR, LCR and HFR
(2.5 mm Veneer)



B. VGRF of A-B, Cp-C-D and Multi's Veneers
(2.5 mm Veneer)



C. VGRF of A, B, Cp and C-D Veneers
(2.5 mm Veneer)



D. VGRF of A, B, Cp, C, D and Multi's Veneers
(2.5 mm Veneer)

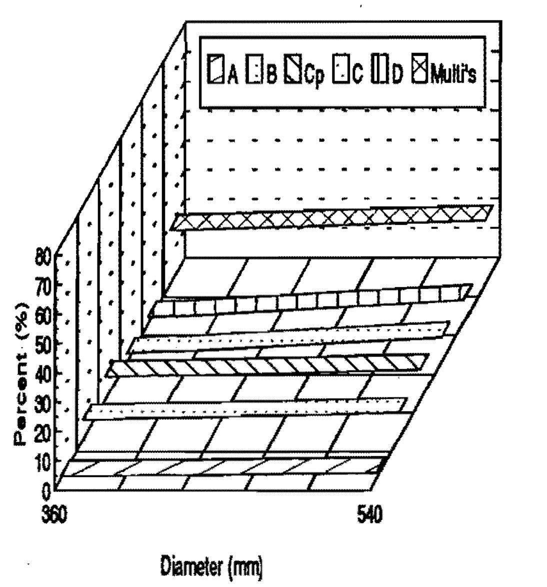
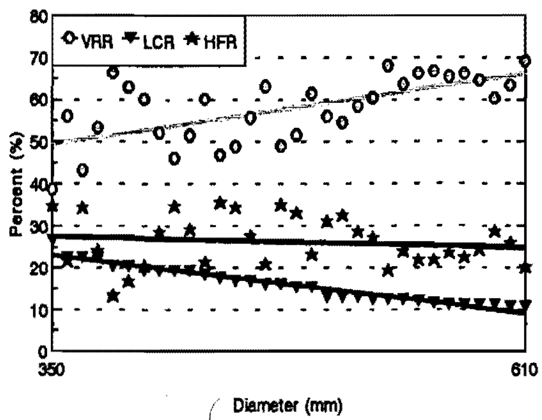
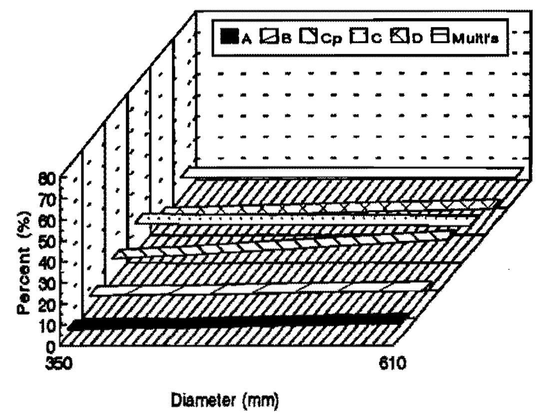


Figure 3-4-3. Veneer recovery of MP logs.

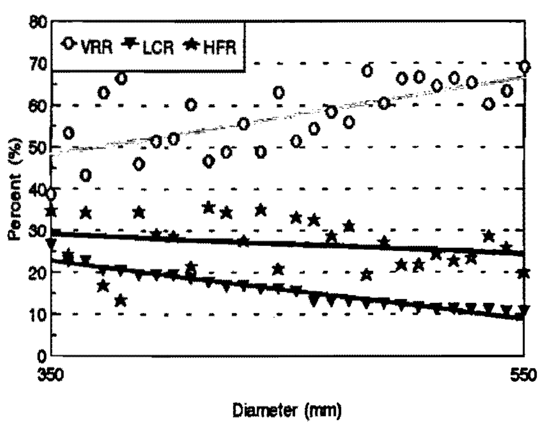
A. VRR, LCR and HFR (2.5 mm and 3.0 mm Veneers)



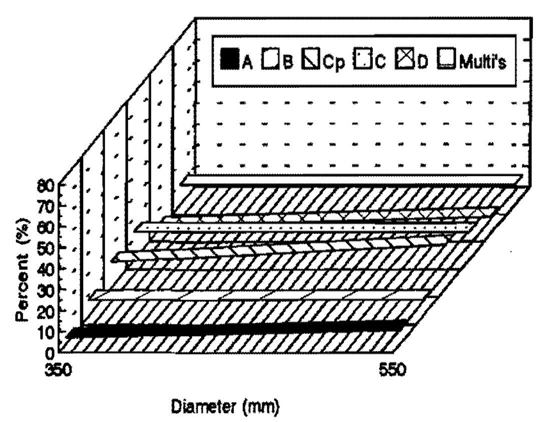
B. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm and 3.0 mm Veneers)



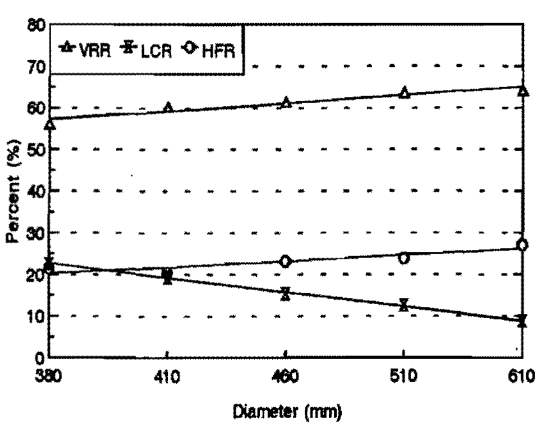
C. VRR, LCR and HFR (2.5 mm Veneer)



D. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm Veneer)



E. VRR, LCR and HFR (3.0 mm Veneer)



F. VGRF of A, B, Cp, C, D and Multi's Veneers (3.0 mm Veneer)

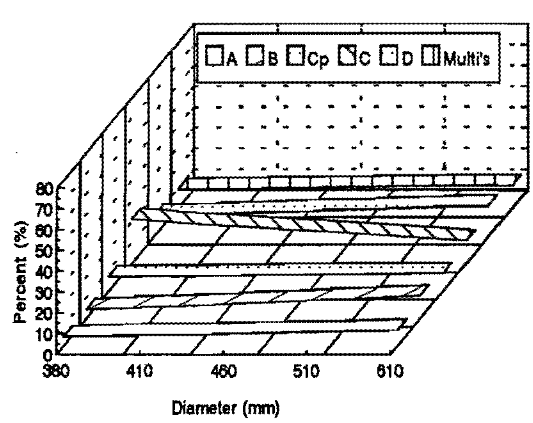


Figure 3-4-4. Veneer recovery of PP logs.

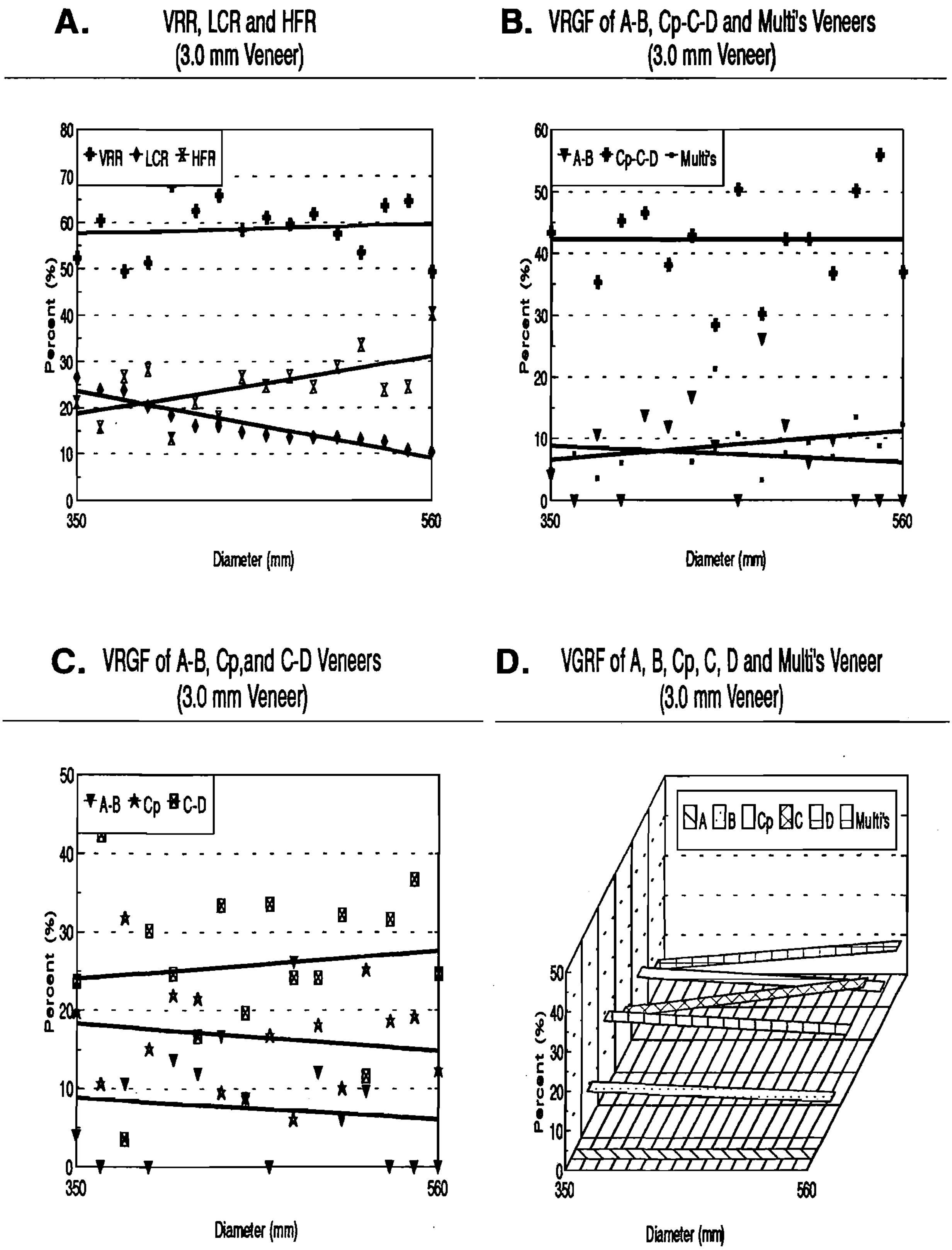


Figure 3-4-5. Veneer recovery of RP logs.

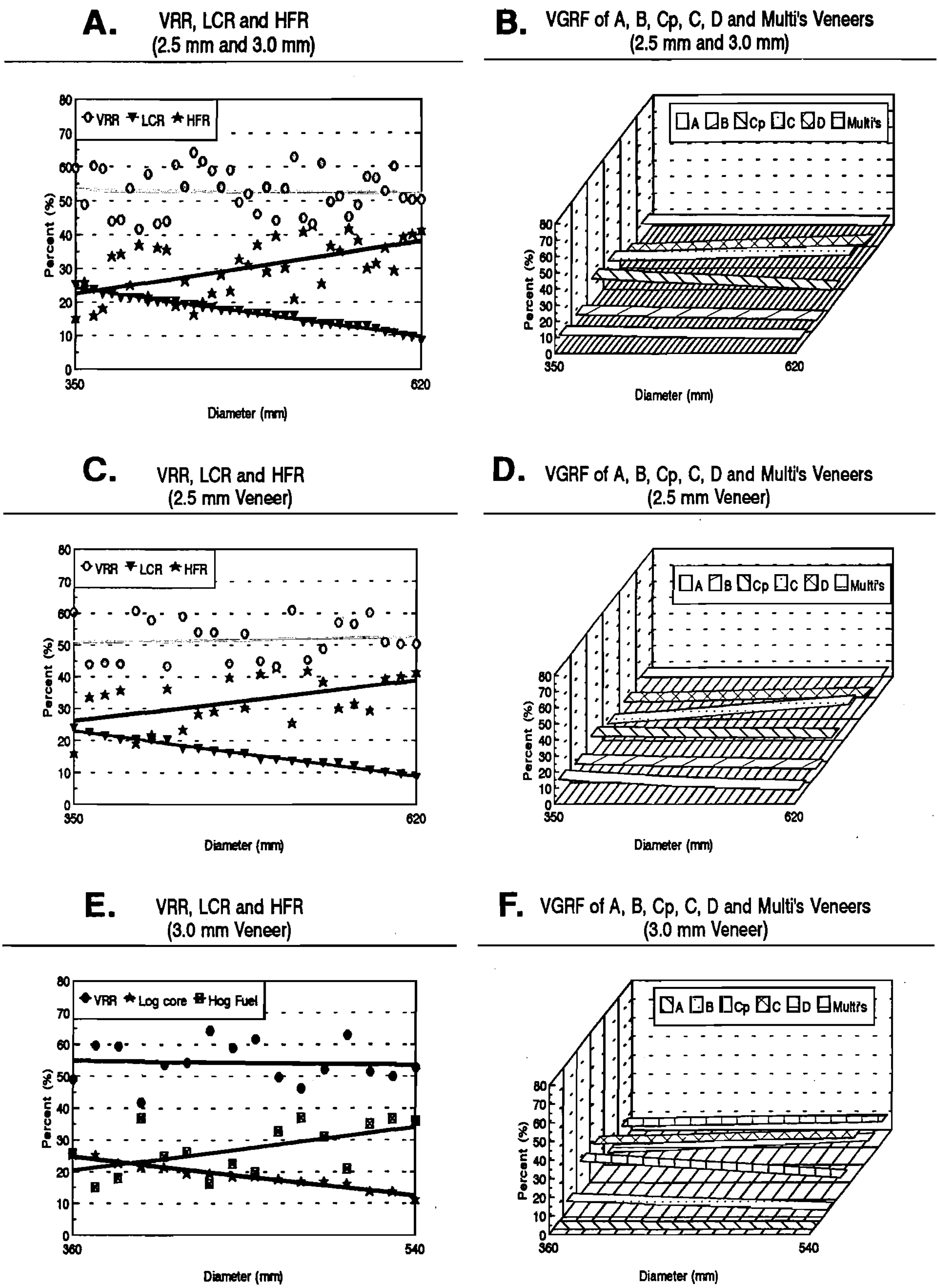


Figure 3-4-6. Veneer recovery of TPB logs.

III. Unpruned Logs

VRR of unpruned logs was higher than for pruned logs. The logs produce veneer grade of Cp, C, D and Multi's only. The clipper operator unwittingly appears to be clipping for volume rather than grade. VRR, Cp and D increase while and C and Multi's decrease, as block SED increases (Figure 3-4-7.i.A). The trend is also observed in both veneer thicknesses (Figure 3-4-7.ii).

In CB logs, VRR remains constant as block SED increases (Figure 3-4-8). Cp veneer remains constant in both veneer thicknesses.

In UP logs, VRR increases as block SED increases. The VGRF of different veneer grades follows the trend of the unpruned logs (Figure 3-4-9).

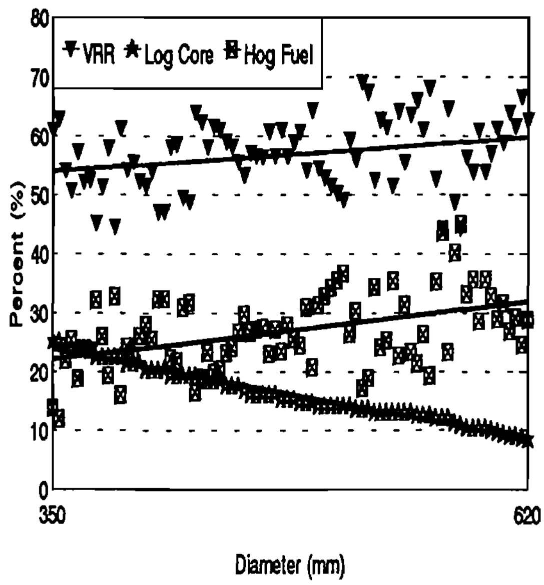
IV. Effect of Veneer Thickness

It was ascertained in this study that the 3.0 mm veneer had higher VRR than 2.5 mm veneer for all source and types of logs as shown in Figures 3-4-1 to 3-4-9. Although statistically not significant in the collective study of pruned and unpruned logs (Equation 3.1) and unpruned logs (Equation 3.3), it was significant in pruned logs (Equation 3.2). The VRR by veneer thickness is one of the important categories and is very important in the structuring of LP models, as will be discussed in Chapter 4.

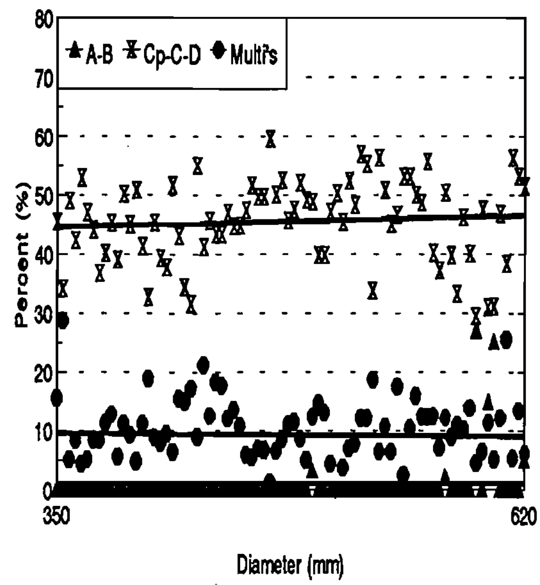
V. Effect of Diameter

The A graphs in Figures 3-4-1 to Figure 3-4-9 show the relationships between VRR, LCR and HFR. LCR decreases as the block or log SED increases. It implies that processing bigger SED logs would yield less log core volume compared to smaller SED logs per cubic metre of log input (although

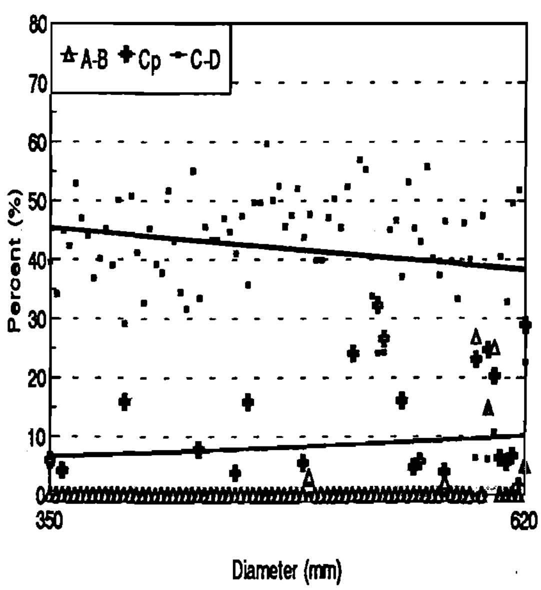
A. VRR, LCR and HFR (2.5 mm and 3.0 mm)



B. VGRF of A-B, Cp-C-D and Multi's Veneers (2.5 mm and 3.0 mm)



C. VGRF of A-B, Cp, and C-D Veneers (2.5 mm and 3.0 mm)



D. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm and 3.0 mm)

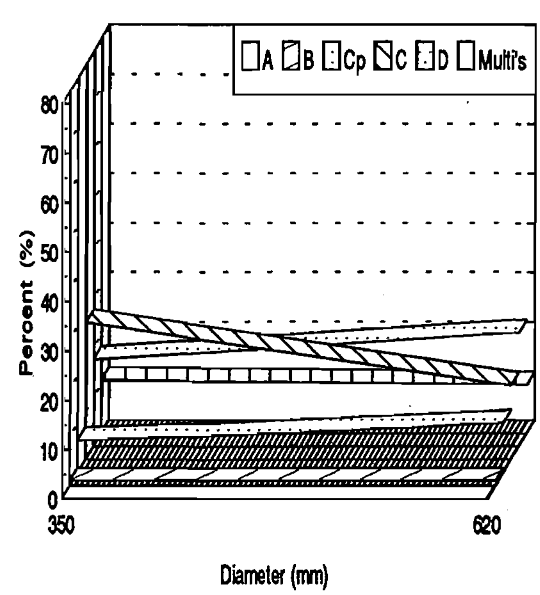
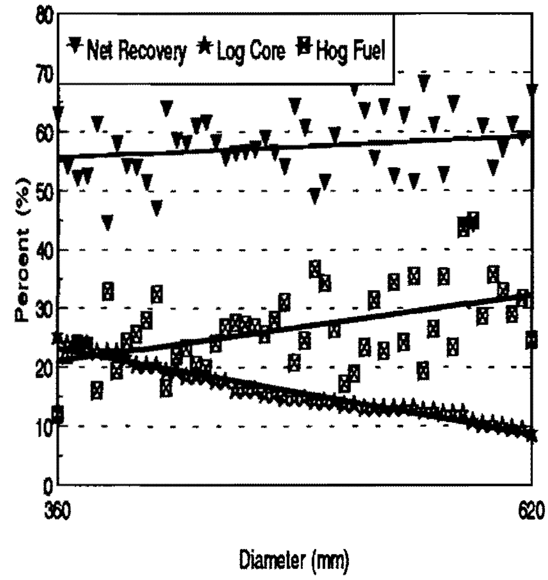
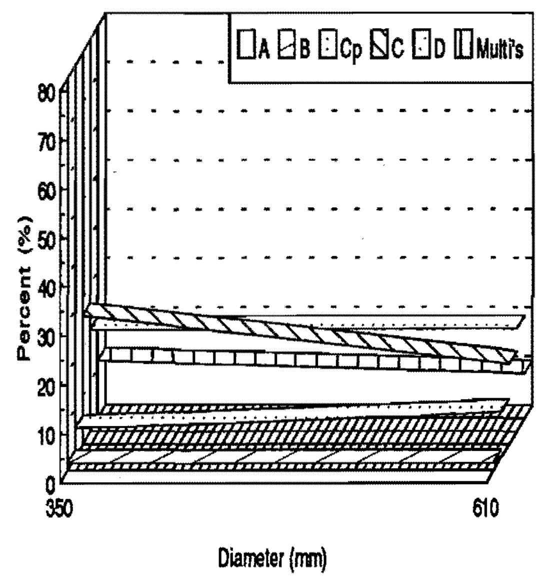


Figure 3-4-7.i. Veneer recovery of unpruned Pinus radiata logs.

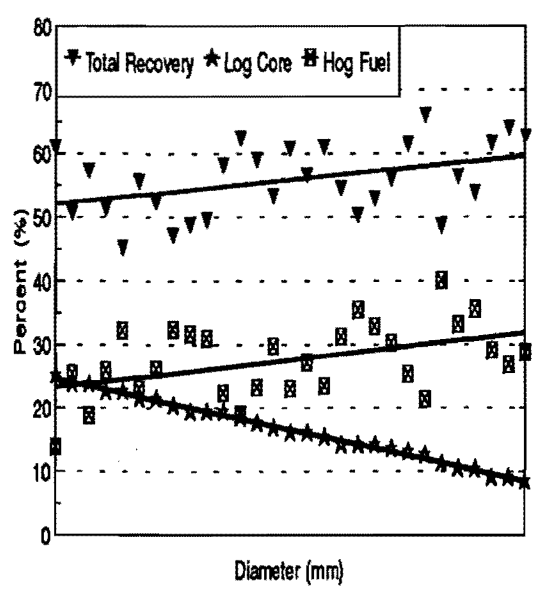
E. VRR, LCR and HFR (2.5 mm Veneer)



F. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm Veneer)



G. VRR,LCR and HFR (3.0 mm Veneer)



H. VGRF of A, B, Cp, C, D and Multi's Veneers (3.0 mm Veneer)

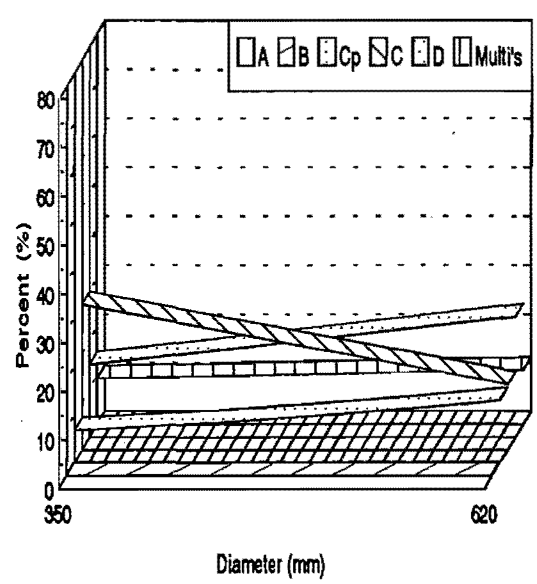


Figure 3-4-7.ii. Veneer recovery of unpruned Pinus radiata logs.

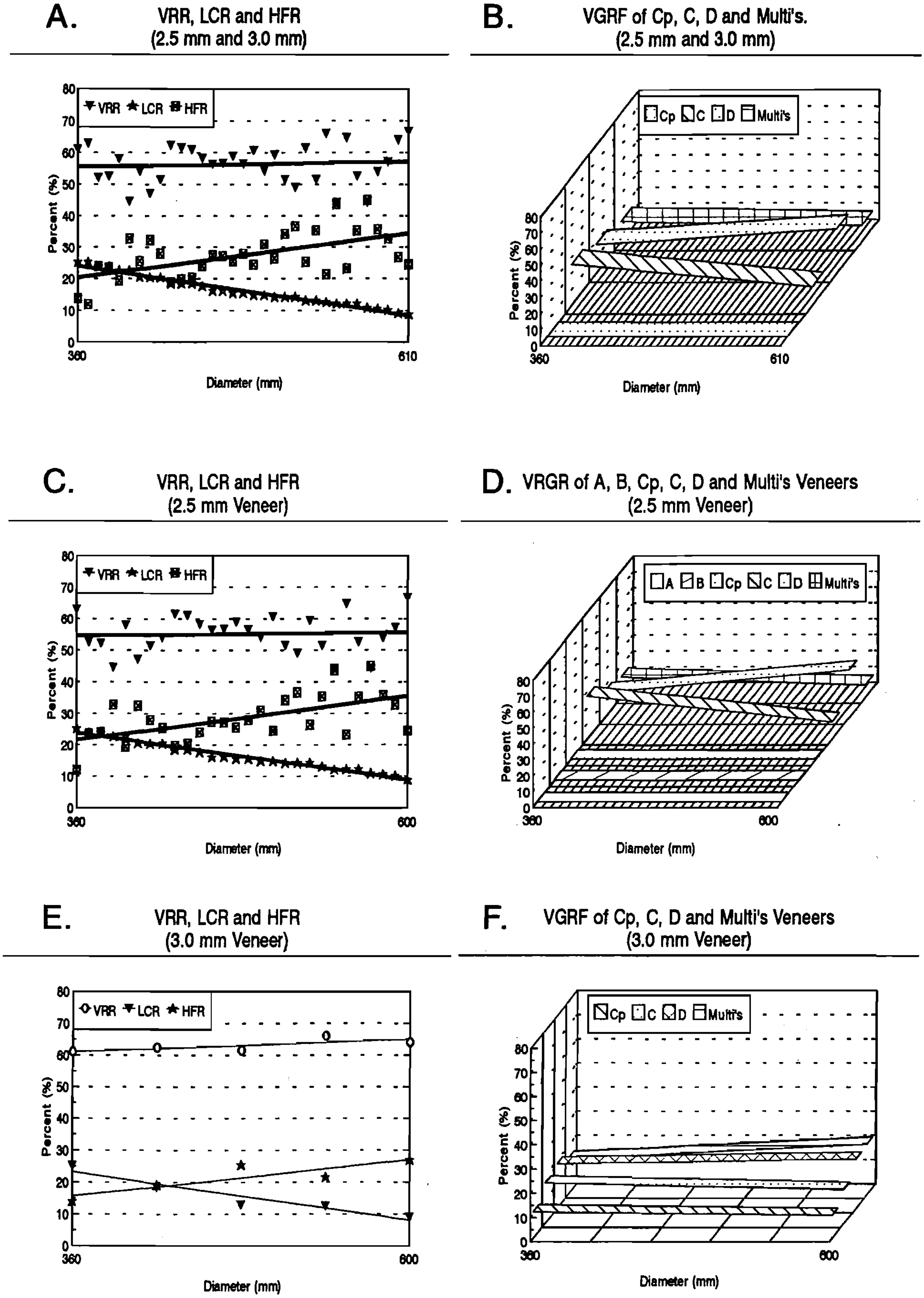
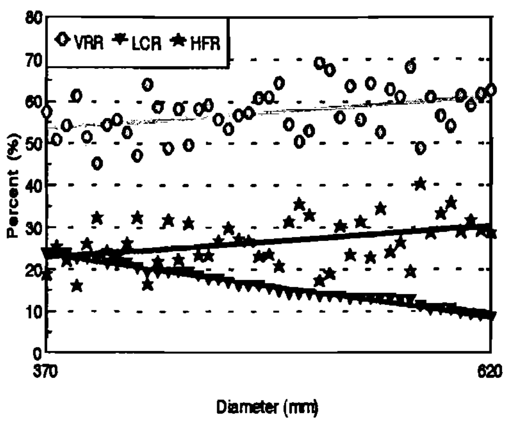
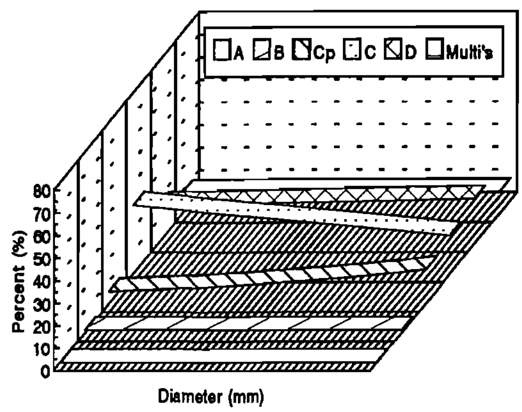


Figure 3-4-8. Veneer recovery of CB logs.

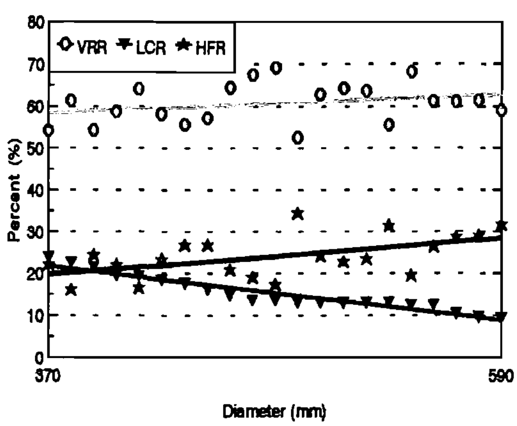
A. VRR, LCR and HFR (2.5 mm and 3.0 mm)



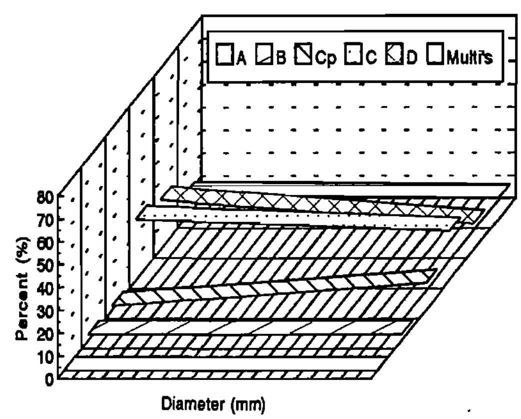
B. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm and 3.0 mm)



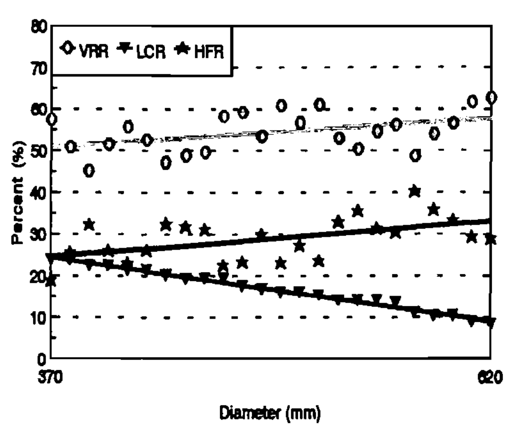
C. VRR, LCR and HFR (2.5 mm Veneer)



D. VGRF of A, B, Cp, C, D and Multi's Veneers (2.5 mm Veneer)



E. VRR, LCR and HFR (3.0 mm Veneer)



F. VGRF of A, B, Cp, C, D and Multi's Veneers (3.0 mm Veneer)

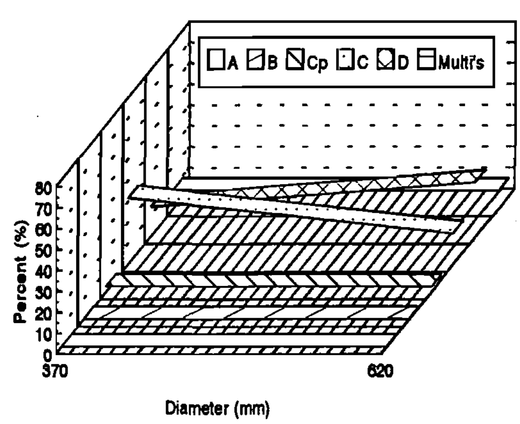


Figure 3-4-9. Veneer recovery of UP logs.

log core volume would be equal per block processed regardless of SED). For example, in Figure 3-4-1.i.A, the log core volume amounted to 24 percent of block volume for the 350 mm SED compared to only 9 percent for 620 mm SED. Thus, processing 1 cubic metre of 350 mm SED would yield 0.24 cubic metres of log cores compared to 0.09 cubic metres of log core for a 620 mm SED block. The trend for HFR, on other hand, is the opposite from LCR and is also shown in the same figure. The HFR increases as the block or log SED increases. The HFR increase can be attributed to log defect core, clipping pattern and other variables in the plant. The log defect core is defined as the cylinder containing pith, branch stubs, and occlusion scars, as well as any widening effects due to stem sinuosity at the time of pruning (Park 1980). The alarming concerns about log defect core should encourage the introduction of a new log grading system, using log defect core data (e.g. proposed Tasman Forestry grading rules by Colley (NZ FI,1992), and presumably it is also a function of the SED of logs. HFR was 24 percent in 350 mm SED compared to 31 percent in 620 mm SED (Figure 3-4-1.A.). Selecting the right diameter of the blocks or logs for production purposes is quite hard to achieve by just basing decisions on the VRR, LCR, HFR and VGRF of different grades without proper log prices and other production costs. Based upon a rule of thumb approach, this information clearly indicates which logs with SED between 350 and 620 mm are the best to process at the one log price as shown in Figure A of the Figures 3-4-1 to 3-4-9. The value of the logs, however, could be best assessed through a systematic approach in which all the production and marketing assumptions including log price, veneer outturn from the logs, veneer prices, opportunities of each veneer grade in the plywood layup option and quantities and prices of ordered product mix, etc are also considered. Proper log valuing could be achieved through a mathematical model such as the LP presented here, which is the main purpose for conducting the recovery study.

3.5 Time Study

Time study or work measurement is a subset of time and motion study in general. The purpose of the time study here was to determine a standard time to perform a specific task (Barnes, 1968). It is often used to evaluate workers' performance to do a job, how the work could be improved, scheduling manpower to improve efficiency, productivity, etc. In this particular study, however, the purpose of time study was to determine the production rate of machines in relation to the new categories of raw material, e.g. SED classes for the logs. The study was conducted to supplement data that were not available for the purpose of modelling.

3.5.1 Objectives of Time Study

The objectives of this time study are:

1. to determine the different rates of machine production for independent machine centres and in accordance with newly categorised sets in the model structure;
2. to determine possible bottlenecks in the existing plant layout; and
3. to standardise the units of measure for production for modelling purposes.

3.5.2 Crane, Cutoff Saw and Debarker

The crane, circular cutoff saw and debarker were considered the first machine centre for evaluation in this time study. As observed in several visits to the plant being studied, this machine centre is not a bottleneck to production. The diameter of the logs has little influence on the time required to load the logs on the chain conveyor and buck them. The rate of debarking blocks is, however, affected by log diameter. In an overall analysis of the machines as one unit, however, the rate of producing debarked blocks to the lathe is not unduly influenced by log size and is also a minor component of the overall production in this particular setup.

Before and after acquisition of the plant from Fletcher Wood Panels, this group of machines was operated by two operators. The new management then realised after a few months that at the rate at which these machines operate, a one man operation would be capable of successfully supplying debarked blocks to the lathe.

3.5.3 Rotary Lathe

In this particular case, the rate at which the lathe peels logs is hindered by the dryer. Lathe production rate is determined and calculated by the number of blocks processed per hour or per eight hour operation as manually tallied by the cutter-debarker and the diameter scanner. At time of the recovery study and this study, the diameter scanner and log counter were not working properly, aside from the fact that it was in an unsuitable position from which to measure log diameter and count the number of logs accurately within a time frame. The log counter was positioned near the end feed of the cut off saw and the scanner was placed in the middle of the conveyor between the debarker and the lathe. Thus, at any given time to start and stop log recovery study by lot (usually done by the management), there is a big discrepancy between the logs counted and diameter of blocks recorded which is the basis of the log volume input, aside from the fact that the veneer counters by grades are placed in the stacker bins. It takes thirty minutes after a block is peeled before the coresponding veneers from that block are dried and stacked in the bins. The log counter, diameter scanner and veneer counters are monitored by one computer which could only be set and stopped at once by turning on and off the computer, while no individual reset is available for its activities in the software. The computer software is not capable of undertaking multitasking at present. The equipment at present is futile for any recovery study as well as determining the rate of the lathe for the modelling purposes.

With the introduction of log SED classes in the recovery study and later in the modelling itself, it was apparent that rates of lathe production according to SED class should be conducted. Thus, the time study was conducted with SED block criteria.

As a prerequisite for any time study, the whole activity has to be broken down into elements. The elements and time elapsed to determine the rate of the lathe by block SED are as follows: i) time 1 (T1), the time required to charge the block, to position it in the lathe and to complete rounding; (ii) time 2 (T2), the time required to peel salvageable roundup for the green clipper; and (iii) time (T3), the time required to peel the remaining wood until the log core is dropped. Delays caused by the dryer were eliminated in order to measure the true rate of the lathe as a machine centre, rather than the relative rate for part of a whole system. Normal time is defined as that time including minor delays. As the block was charged into the lathe, SED's were measured and recorded together with the time elapsed in the three elements to determine the rate of the lathe by block SED. Results are in Appendix C.I. With these results the technological coefficients of the lathe as part of the production constraints in LP modelling will improve its accuracy in allocating the logs according to SED classes and not just on the overall veneer recovery figures. This is a very important aspect in representing the production side of the operations especially in evaluating effect of one machine centre to another (e.g. tracing up bottleneck machines and evaluating the value of machine time through their dual values).

3.5.4 Continuous Dryer

Dryer production rates could be determined simply by the drying speed in terms of veneer thickness. There is no need for a time study. But, again SED classes of blocks established played an important part in determining the drying rates for the model coefficients. As discussed earlier, in this plant, the veneers were dried in ribbons rather than the usual practice of drying standard sizes and defect free sheets. The traditional way of computing the time required to dry the output veneer from the recovery study figures would not provide the requisite detail for providing coefficients for the LP models. The gross volumes of veneer including veneer defects from an individual block, which are fed and dried, are should be the basis for determining drying rate coefficients of the dryer for LP models. Thus, dryer productivity by SED classes and time required to dry the veneers are used in the models. The results are shown in Appendix C.II. The results also affect the outcome of log allocation in LP modelling and its sensitivities to change constraint-programming, especially since the dryer seems to be the major production bottleneck.

3.5.5 Stringing

At present, the output rate of the stringer or the Hasimoto as the machine is commonly known in the plant, was determined by the number of unitised full sheets per hour regardless of the grade of veneers. It should be noted that multi's veneer comprises clear multi's as well as simply multi's. The clear multi's are random width veneers of grade A and B and could be upgraded to be called HCp or Hasimoto Cp, which is one of the layup options for face veneers in Cp grade plywood for the Hongkong / Asian market, and crossbands (full sheets in between the corestocks and face or back) in the specialties plywood for furniture which require clear crossbands for grooving purpose. The multi's veneers are of grade C and D generally and solely used as corestock and crossbands. The rate of the stringer to produce full sheets depends on the type of multi's. Thus, a time study was conducted on the clear multi's and multi's veneers. Results are shown in Appendix C.III. Again, log allocation as well as veneer allocation depend on the rate of production on the stringer and available HCp and unitised multi's known as multiple crossbands (MXB).

3.5.6 Glue Spreader

With the new categories of the corestocks (full sheet and MXB) being fed to the glue spreader, the glue spreader productivity as a machine centre to produce assembled panels for pressing was greatly affected by the type of corestock. Plywood thickness layup would not affect the productivity of the 3 man crew, but quality and number of corestocks passing through the spreader and utilised in the layup or assembled panel do influence the production rate directly. Currently, the type of corestocks is not used as a category to determine the productivity of the spreader. Thus, a time study was conducted for the two types of corestocks, since it is a necessary component in the LP modelling.

In the time study, the unutilized corestock which create uneven glue spread, partially attributed to thin-or-thick veneer as discussed earlier, was not counted. The number of corestocks utilised in a layup per minute was determined per type of corestock. Results are shown in Appendix C.IV. The rate of spreader production when using the unitised multi's (MXB) is slower than the full sheets. This is also the reason why some foremen have better productivity than others, because full sheets of C grade are cut in half for corestock and substituted for MXB scheduled in the layup option. Management often supports higher productivity but the real business game should be profitability which is what this whole study is about.

3.5.7 Hot Press and Trimsaws

The rate of production through the hotpress is dependent on the number of hot press openings and pressing time of the panel which is a function of plywood thickness, density of wood, type of adhesive, hot platten temperature and pressure. Often plant capacity is measured in terms of the hot press rate which is synonymous to rated capacity of the plant. In this and most other plants, a hot press standard operating procedure is a carefully documented aspect of the whole operation; thus, the hot press rate per thickness could be easily computed for modelling purposes. Proper documentation of the press procedure is necessary because hot pressing activity determines the quality of the panel produced. The results of production rates of the hot press per plywood thickness and trimsaws at one machine centre is shown in Appendix C.V.

3.5.8 Sander, Grader and Stacker Rate

The number of panels sanded, graded and stacked was also determine by the time study. The rate is not a function of the plywood thickness but of the surface area which is the same in all plywood, regardless of thickness. The results of the study and calculated output rate of this machine centre is shown in Appendix C.VI.

3.5.9 Implication of the Time Study

In summary, the time studies to determine the production rates of the machines, to represent the machine centre concept, is an important part of data collection for characterising any plant, but is especially vital when the models to be built address the area of operational planning. Operational scheduling is an aspect to be studied here. The precision of the production rates of the machines for certain input categories (e.g. log SED classes, veneer thickness, type of corestocks, panel thickness, etc.) is a very important factor to consider in different planning horizons. For example, in operational planning the time horizon is short and the data needed should be concise and detailed to suit the purpose of modelling. The results of the time studies conducted here produce the technological coefficients of the individual machine constraints or whole production constraints in the LP modelling which fully complement the new categories contained in the resource constraints and to achieve greater sensitivity in the what-if scenarios of production for the change-constraints programming.

This chapter has explained the importance of the methods of collecting production data in structuring efficient LP models that can be used at strategic, tactical and operational planning levels. The next chapter, Chapter 4 presents the modelling philosophy and structures of the models in which log SED class, new categories of materials and their machining rates discussed in this chapter, are main elements in the formulation of the models. Chapter 5 presents and discusses the whole database needed to formulate a computer model and its implementation.

Chapter 4

The Models: LOGPLY and VENPLY

Wood processing mills are an integral part of a forest sector and have a major bearing on commercial forest resource management and planning activities, since they are established primarily as a means of obtaining economic benefit from forest resources in general. As integrated forest products companies expand, however, the planning and management of the forest and forest products operations are often decentralised. Consequently, they are managed separately and viewed as different business units and profit centres. Because of this approach, forest sector planners have broadened their planning strategies through designing strategic planning models that focus not only on resource allocation for growing and tending trees but more on log allocation to mills, processing requirements of the mills within a region and marketing potential of the products derived from the all resources (Gunn, 1991; Johnson and Whyte, 1991). On the other hand, solid wood forest products industries, sawmillers and veneer and plywood manufacturers, still concentrate on the role of efficient utilisation of raw material by achieving higher recovery in production rather than on economic efficiency of the mills. Nevertheless, several studies in veneer and plywood models, as discussed in Chapter 2 document how overall planning requirements can be addressed starting with traditional resource allocation problems through to the product mix problems. But most of these models focused either on the resources or the production aspects of the operation. The inter-dependency of raw material resources, production and marketing aspects of the overall or global business operation is not fully investigated. Moreover, the concept of hierarchical planning systems has not been addressed. Few general mathematical models have been developed for combined strategic, tactical and operational planning. Furthermore, production managers have little understanding of how models work in order to address detailed technicalities and multi-faceted forest product industry operations such as veneer and plywood manufacturing. Thus, there is a need for such models to respond not only to the production environment but also to log resource procurement strategies and market-oriented manufacturing. Accordingly, a holistic approach to modelling is necessary in order to consider properly the effects of different factors in achieving greater profitability and mill economic efficiency.

Log to plywood (LOGPLY) and veneer to plywood (VENPLY) planning models described here are attempts to produce resource-oriented, market-oriented, profit-maximising, manufacturing LP models in line with the objectives defined in Chapter 1. This chapter outlines the modelling philosophy and background, the influence diagram - tool for the development of models, mathematical formulation, model structure, unique features of model implementation, hierarchical planning system and functions of the models.

4.1 Modelling Philosophy and Background

LOGPLY and VENPLY have been developed as a framework for providing a decision support system for the overall decision-making in veneer and plywood operations. The models closely examine the interdependency of log resource, production environment and markets from a managerial viewpoint. The inter-relationships will be fully discussed in detail later in part 4.2. The two models work in tandem to address fully the: (1) log procurement, price, mix and allocation; (2) veneer valuation; (3) veneer requirements; (4) optimal layups and product mix determination; (5) evaluation of new products; (6) plant capacity planning; (7) machine performance; (8) production scheduling and control; (9) production and market coordination; (10) marketing; and (11) investment options. These universal needs of any veneer and plywood operation will each be addressed later in this chapter.

The models were also built to demonstrate their potential for hierarchical planning systems to respond to operational needs at strategic, tactical and operational levels for both production and marketing. Thus, the models provide: (i) a working plan from a strategic planning point of view; and (ii) operating plans for production when the models are used at the tactical and operation planning levels. Detailed discussion of these topics will be in part 4.5.

The user-friendliness of the system, moreover, was deliberately planned in order to: (i) simplify and disguise the technical complexity of the model, (ii) eliminate the difficulty of routinely implementing mathematical models and (iii) create a more effective communication mechanism between the routine use of models and managers' decision-making (e.g. simulating production and market conditions routinely, by updating the technological and resource coefficients to explore alternative solutions in order to achieve greater profitability). The system has a user-friendly interface for data input and sensitivity analysis of the output, customised accounting and management reports with business graphics (e.g. bar charts).

Model implementation using spreadsheets provides a real-time solution for operational planning, especially in the areas of scheduling and material requirement planning (mass balance) to meet the needs of market-oriented manufacturing. Promotion of an effective interactive user interface provides greater flexibility to respond to real production and marketing scenarios facing business managers.

Detailed discussion on the implementation of a working computer model is contained in Chapter 5.

4.2 Influence Diagram

Visualising and understanding how a mathematical model works to respond to the real world problem and characteristics of a certain operation to be modelled (e.g. veneer and plywood manufacture) is an important task of modelling. Unfortunately, the utility of most models is not fully appreciated nor is their utility given enough consideration by the managers who really need them, primarily because they are not properly presented to fit the manager's cognitive style, aside from technical complexities. In many cases the mathematical model, often expressed as a series of equations, serves poorly as a tool for communication to users as well as a means of structuring a model. Thus, managers' appreciation of mathematical models is often superficial. The purpose of presenting an influence diagram as a general graphical illustration, is to; (i) display both the problem and frame of the concept of the model; (ii) represent the structure of the model; (iii) explain the information structure of the model; and (iv) serve as the framework for expressing more specifically the exact nature of the influence relationships (Bodily, 1985).

Before constructing an influence diagram for models, it is necessary to grasp and understand fully in detail the inter-relationships of log resource, production environment and marketing factors, and how they affect the management of a veneer and plywood business. As mentioned earlier, veneer and plywood manufacturing is not simply a process of making the best quality products with the greatest efficiencies of production, but the interdependency of raw material resource, production environment and marketing factors. The inter-relationships of these factors are shown in Figure 4-1. In this diagram, the two-stage problem consisting of peeling logs into

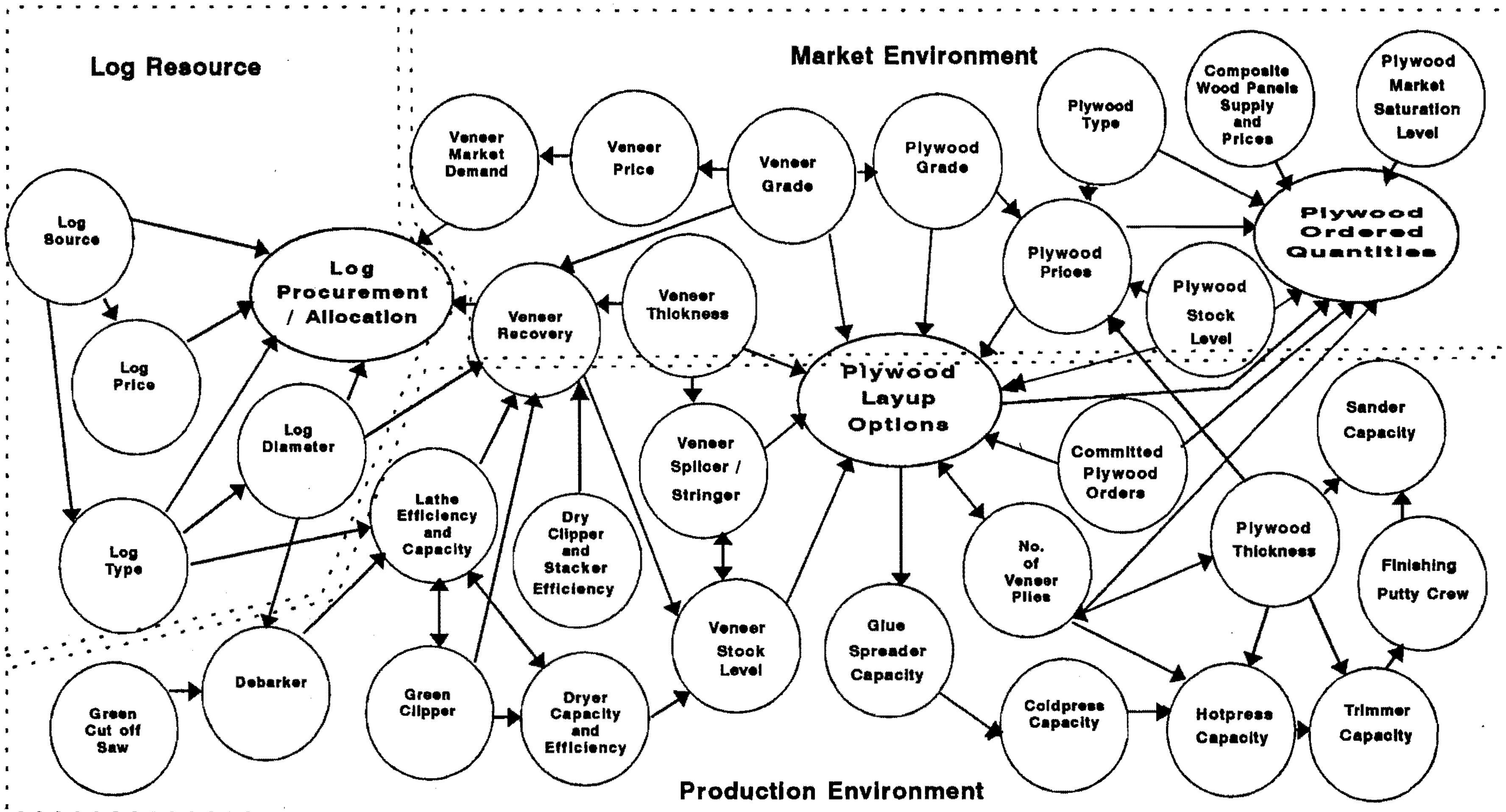


Figure 4-1. Interactions of the factors affecting veneer and plywood production and marketing.

veneers and subsequently laying up these veneers into plywood panels which some modellers (e.g. Donnelly, 1966; Ramsing, 1968; Spelter, 1990) have perceived, is now extended to a three-stage problem. The reality is, the problem actually involves three major decisions, comprising: (i) log procurement / allocation by type, diameter and source; (ii) panel layup options by veneer grade and thickness; and (iii) product mix volume combination by grade, thickness in relation for the market. The third dimension represents the need to address the concept of market-oriented manufacturing which may be defined as producing the "right products" which have high "opportunity value" from the right raw material, production resources and intended market. The inter-relationships of the factors give rise to development of LOGPLY and VENPLY. The influence diagram is shown in Figure 4-2. In this diagram, the decision variable (rectangles), intermediate variables (circles), and outcome attributes (ellipses) that pertain to a problem, along with the influencing relationships among them are depicted. This particular influence diagram is designed to suit managers' understanding of the problem, its needs and scope. A detailed influence diagram is not necessary in this case since Figure 4-1 already describes interactions of these factors. Influence diagrams can be more detailed to some extent depending on the audience's level of understanding about the problem to be modelled. In the diagram, the arrows indicate the direction of influence. The + sign indicates that the variables changes in similar direction whilst a - sign indicates opposite direction of change; thus for example an increase in veneer and plywood volume and prices, assuming other things equal, results in an increase of total gross revenue. The tilde (~) indicates that the variable is exogenous or random (e.g. price).

The influence diagram presented is simple enough to be understood (as is one of its purpose) without a detailed technical knowledge of plywood manufacturing. There is no need at this point for further clarification and explanation on how the

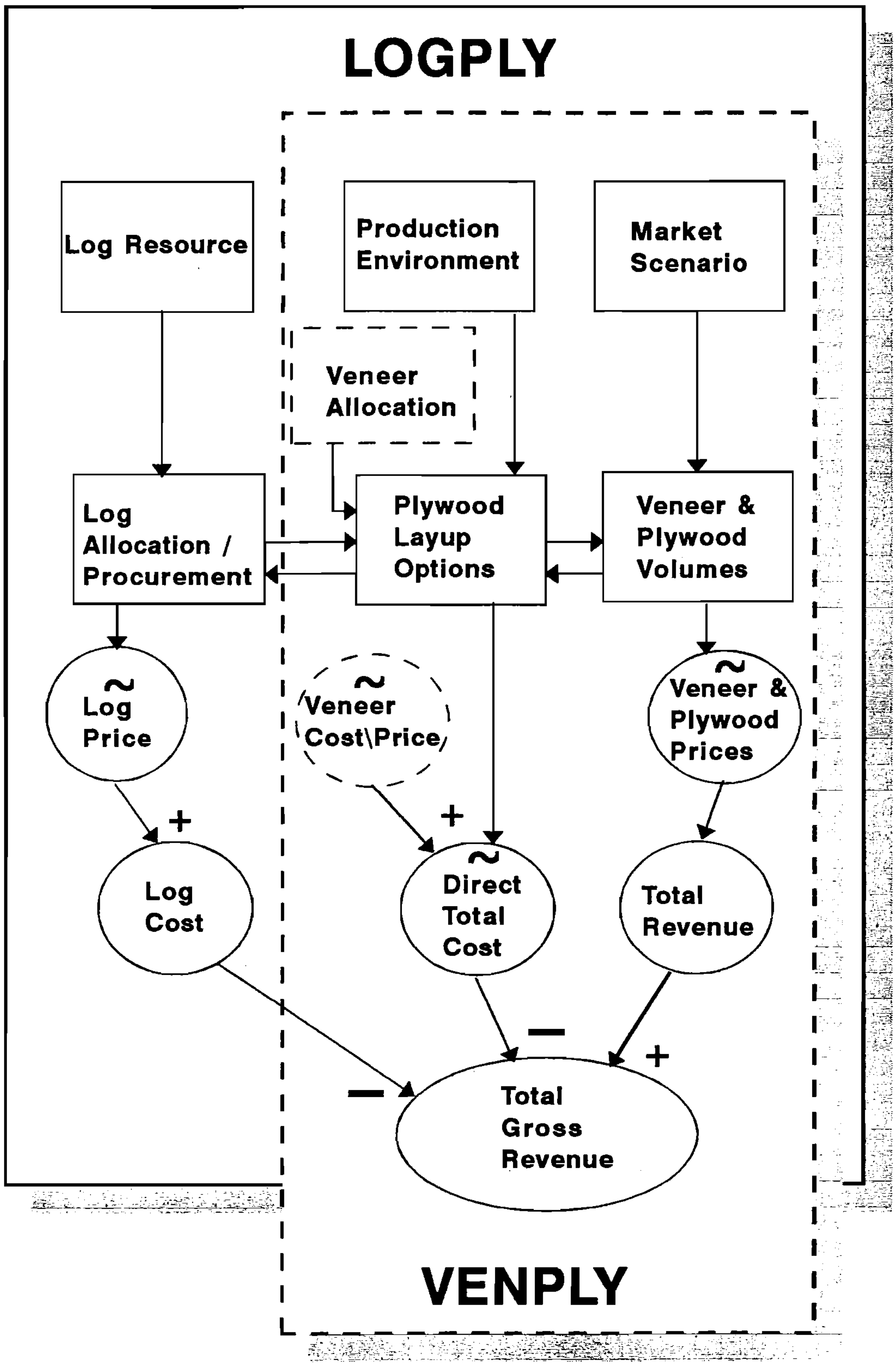


Figure 4-2. Influence Diagram of the Models.

models would work to address the global needs of a veneer and plywood operations as affected by the log resource, production environment and market. That is presented later in Chapter 6. The diagrams help bridge the gap between the manager who would like to design decision aid or to understand the design of decision aid, the problem and the mathematical model.

4.3 The Mathematical Models

In general LOGPLY and VENPLY were formulated as linear programmes (LP). The two models assume an objective of maximising either the net revenue or net profit as the case maybe, accruing to a veneer and plywood operation over a specified planning horizon. The objectives of the models are subject to constraints and restrictions in raw material resources, production environment and marketing factors, which are discussed earlier and shown in Figures 4-1 and 4-2. The fundamental unit of the analysis of the models is a "product grade" which will be explained in part 4.5.

LOGPLY deals with converting logs to plywood. It decides the allocation of quantities of logs from a choice of different sources, log types and log dimensions to produce desired mixes of veneer for the product mix (veneer and plywood products). Intermediate activities consist of peeling the logs to produce veneers of different thicknesses and grades,(together with byproducts of hog fuel and log cores), splicing less than full width veneers (upgrading random width veneers, multiples and fishtails into core veneers), and finally allocating veneers to markets without further processing (veneer sales), if profitable, and to various layup options for making a range of plywood products. Veneers by grade and thickness are treated as intermediate products as well as commodities in inventory for the market in this model. The model has a downgrading mechanism for veneer which maintains a zero level of veneer inventory for material balance. Machine productivity constraints, starting with the rotary lathe and extending to the sander, characterise the realities of veneer and plywood constrained production. The final activities consist of allocating plywood by panel thickness and grade to relevant markets and veneer sales with upper and lower limit volumes. Three capacity options were included in the model: (i) log input, (ii) veneer output (veneer sales and plywood layup) and (iii) plywood product output.

VENPLY deals simply with converting veneers to plywood products. It is a subset of LOGPLY. The primary input of the model is the dry untrimmed veneer inventory by grade and thickness, rather than the mix of log types that needs to be obtained. The structure of the model is very similar to LOGPLY, the only difference being that the model starts with veneer. The veneers are thus treated as both a raw material input and at the same time a commodity for the market. The machine constraints in VENPLY start with the splicer and end with the sander. The same plywood layup options and marketing constraints as in LOGPLY are used in VENPLY. Two capacity option namely; (i) veneer output and (ii) plywood product output are incorporated in the model.

4.4 Mathematical Formulation

The two models were defined in a mathematical formulation using the indices, variables and notation listed in Table 4-1, which consists of functions relating the variables in forms that translate their relationships into system of equations. The formulation of the two models meets the assumptions of linear programming viz., linearity, divisibility, nonnegativity and deterministic variables and coefficients.

Table 4-1. Description of LOGPLY and VENPLY indices, decision variables and parameters.

Symbol	Definition
Indices	
s	source of logs ($s = s_1, s_2, \ldots, S$)
l	type of logs ($l = l_1, l_2, \ldots, L$)
d	small end diameter class ($d = d_1, d_2, \ldots, D$)
h	nominal thickness of veneer ($h = h_1, h_2, \ldots, H$)
g	grade of product (veneer or plywood) ($g = g_1, g_2, \ldots, G$)
j	veneer grade grouping ($j = j_1, j_2, \ldots, J$)
m	panel thickness ($m = m_1, m_2, \ldots, M$)
o	panel layup option ($o = o_1, o_2, \ldots, O$)
c	type of corestocks ($c = c_1, c_2, \ldots, C$)
i	machine centres ($i = i_1, i_2, \ldots, I$)
T	Time period (annual, quarter or fortnightly)
Decision variables	
XL_{std}	Volume of logs to be procured or processed by source, type and diameter class
XV_{hg}	Volume of veneer to be procured/produced or allocated as the case maybe by thickness and grade
XVM_{hg}	Volume of veneer to be upgraded (spliced\stringed) by thickness and grade
XVA_{hg}	Volume of veneer accounted for veneer sale option by thickness and veneer grade
XVS_{hj}	Volume of veneer to be sold by veneer thickness and veneer grade grouping
XVD_{hg}	Volume of veneer to be downgraded by thickness and veneer grade
XP_{mgo}	Volume of panel to be sold by panel thickness, grade and layup option
XML_d	Lathe & Clipper time to be allocated to different diameter classes
XMD_h	Dryer time to be allocated to different veneer thicknesses
XMS_g	Splicer/Stringer time to be allocated to different multi grade veneers
XMG_m	Glue spreader time to be allocated to different panel thicknesses and grades
XMH_{mg}	Hotpress time to be allocated to different panel thicknesses and grades
$XMSD_{mg}$	Sander time to be allocated to different panel thicknesses and grades
Parameters	
PL_{sld}	Price/cost of log by source, log type and diameter class
CV_{hg}	Price/cost of veneer to be procured, produced or allocated as case maybe by thickness and grade
PCL	Selling price of log core
LCR_{sld}	Percent volume of log converted into log core (log core ratio) by source, log type & diameter class

Table 4-1. (cont.)

Symbol	Definition
Parameters	
PC	Selling price of chips (hog fuel)
HFR_{sld}	Percent volume of log converted into chips/hog fuel (hog fuel ratio) by source, log type & diameter class
CPV_{hg}	Cost of upgrading veneer by thickness and grade (stringing)
CDV_{hg}	Cost of downgrading veneer by thickness and grade
PV_{hj}	Selling price of veneer by thickness and grade grouping
PP_{mgo}	Selling price of panel by thickness and grade
CPP_{mgo}	Variable cost of producing by panel thickness, grade and layup option
$VGRF_{sldh}$	Veneer grade recovery factor by log source, type, diameter class and veneer thickness
PCF_{mgo}	Panel conversion factor by panel thickness, grade and layup option
QL_{sld}	Volume of available logs by source, log type and diameter class
QVA_{hg}	Volume of available veneer by thickness and grade
$QVmin_{hj}$	Forecasted or ordered veneer minimum quantity by thickness and veneer grade grouping
$QVmax_{hj}$	Forecasted or ordered veneer maximum quantity by thickness and veneer grade grouping
$QPmin_{mg}$	Forecasted or ordered panel minimum quantity by thickness and grade
$QPmax_{mg}$	Forecasted or ordered panel maximum quantity by thickness and grade
QTL_T	Total volume of logs that could be processed in the plant during period T
QTV_T	Total volume of veneer that could be produced in the plant during period T
QTP_T	Total volume of plywood that could be produced in the plant during period T
LR_d	Lathe and Clipper rate by diameter class
DR_h	Dryer rate by veneer thickness
SR_g	Splicer / Stinger rate by veneer grade
GR_c	Glue spreader rate by core grade (spliced or full sheet)
HR_m	Hotpress rate by panel thickness
AT_{lathe}	Lathe and Clipper available time during period T
AT_{dryer}	Dryer available time during period T
$AT_{splicer}$	Splicer / Stinger time available during period T
$AT_{spreader}$	Spreader time available during period T
$AT_{hotpress}$	Hotpress time available during period T
AT_{sander}	Sander time available during period T

4.4.1 Objective Function

Equations 4.1 and 4.2 state the objective of LOGPLY and VENPLY, respectively: the maximisation of net profit to a veneer and plywood operation.

LOGPLY:

$$Maximise\ Z = R_T - WC_T - UC_T - DC_T \tag{4.1}$$

VENPLY:

$$Maximise\ Z = R_T - VC_T - UC_T - DC_T \tag{4.2}$$

Where:

$$R_T = \sum_{h=h_1}^{H} \sum_{j=j_1}^{J} PV_{hj} * XVS_{hj} + \sum_{m=m_1}^{M} \sum_{g=g_1}^{G} \sum_{o=o_1}^{O} (PP_{mgo} - CPP_{mgo}) * XP_{mgo} \tag{4.3}$$

= the total gross revenue accruing during period T from the sales of all intermediate products (veneer by thickness h and grade grouping j) and all final products (plywood by thickness m, grade g and layup option o).

$$WC_T = \sum_{s=s_1}^{S} \sum_{l=l_1}^{L} \sum_{d=d_1}^{D} ((- PL_{sld} + (PLC * LCR_{sld}) + (PC * HFR_{sld})) * XL_{sld} \tag{4.4}$$

= the total wood cost for all logs from all log sources s, types l and diameter classes d less the revenue gained from the sales of byproducts (log core and hog fuel).

$$VC_T = \sum_{h=h_1}^{H} \sum_{g=g_1}^{G} CV_{hg} * XV_{hg} \tag{4.5}$$

= the total cost of veneer to be produced, procured or allocated as the case maybe from different veneer thicknesses *m* and grades *g* for the product mix during period *T*.

$$UC_T = \sum_{h=h_1}^{H} \sum_{g=g_1}^{G} CPV_{hg} * XV_{hg} \tag{4.6}$$

= the total cost of veneer upgrading from the different veneer thicknesses *h* and grades *g*.

$$DC_T = \sum_{h=h_1}^{H} \sum_{g=g_1}^{G} CDV_{hg} * XVD_{hg} \tag{4.7}$$

= the total cost of veneer downgrading from all veneer thicknesses *h* and grade *g*.

4.4.2 Constraints

The following constraints represent several factors identified and observed to have a significant limiting effect on veneer and plywood operations. Although the LOGPLY and VENPLY models are implemented in a spreadsheet environment that could be altered and modified easily to suit planning needs and time horizon (see Chapter 6), the constraints listed here are likely to be the most constraining factors in the veneer and plywood operation.

I. Wood Resource Supplies

A. Log availability \ Log Procurement for LOGPLY Model

$$\sum_{s=s_1}^{S}\sum_{l=l_1}^{L}\sum_{d=d_1}^{D} XL_{sld} \leq \sum_{s=s_1}^{S}\sum_{l=l_1}^{L}\sum_{d=d_1}^{D} QL_{sld} \qquad (4.8)$$

The total amount of logs to be allocated from different log sources *s*, types *l* and diameter classes *d* in period *T* using LOGPLY, which must not exceed the available log supply in the given period *T*. However, in the *de novo* programming approach (to be discussed later in part 4.6.2), the total amount of logs by source, type and diameter class to be procured for the production of the product mix can be designed optimally.

B. Veneer availability \ Veneer production for VENPLY Model

$$\sum_{h=h_1}^{H}\sum_{g=g_1}^{G} XV_{hg} \leq \sum_{h=h_1}^{H}\sum_{g=g_1}^{G} QVA_{hg} \qquad (4.9)$$

The total amount of veneers to be allocated from different veneer thickness *m* and grade *g* in period *T* using VENPLY, must not exceed inventory veneers in period *T*. In the *de novo* programming approach, the total amount of veneers to be produced is that which achieves an optimal system design.

II. Intermediate product material balance

$$\sum_{s=s_1}^{S}\sum_{l=l_1}^{L}\sum_{d=d_1}^{D}\sum_{h=h_1}^{H} -VGRF_{sldhg}*XL_{sldh} + \sum_{h=h_1}^{H}\sum_{g=g_1}^{G} XVM_{hg} + \sum_{h=h_1}^{H}\sum_{g=g_1}^{G} XVA_{hg}$$
$$+ \sum_{h=h_1}^{H}\sum_{g=g_1}^{G} XVD_{hg} + \sum_{m=m_1}^{M}\sum_{g=g_1}^{G}\sum_{o=o_1}^{O} PCF_{mgo}*XP_{mgo} = 0 \qquad (4.10)$$

The amount of veneers to be produced by thickness *h* and grade *g* from logs is the sum of that derived from all log sources *s*, types *l* and diameter classes *d*, then subsequently upgraded and downgraded as the case maybe. This quantity must be equal to all veneers allocated to different layup options *o*, by panel thickness *m* and grade *g*, and to all veneers allocated to be sold in market *j* during period *T*.

III. Production Capacity Limits

A. Log Plant Capacity

$$\sum_{s=s_1}^{S} \sum_{l=l_1}^{L} \sum_{d=d_1}^{D} XL_{sld} \leq QTL \tag{4.11}$$

The total volume of logs from all sources *s*, types *l* and diameter classes *d* to be processed, and from which the product mix is produced. It must not exceed the log capacity of the plant which has been set for the period *T*.

B. Veneer Plant Capacity (Veneer Output)

$$\sum_{h=h_1}^{H} \sum_{g=g_1}^{G} XVS_{hg} + \sum_{m=m_1}^{M} \sum_{g=g_1}^{G} \sum_{o=o_1}^{O} PCF_{mgo} * XP_{mgo} \leq QTV \tag{4.12}$$

The total volume of veneers allocated by thickness *h* and grade *g* to produce the product mix (veneer and plywood). It must not exceed the veneer capacity of the plant set during period *T*.

C. Plywood Plant Capacity (Panel Output)

$$\sum_{m=m_1}^{M} \sum_{g=g_1}^{G} \sum_{o=o_1}^{O} XP_{mgo} \leq QTP \tag{4.13}$$

The total volume of veneers allocated by thickness *h* and grade *g* to produce the product mix (plywood only). It must not exceed the plywood capacity of the plant set during period *T*.

IV. Machine Centre Constraints

A. Lathe and Clipper

$$\sum_{d=d_1}^{D} LR_d * XML_d \leq AT_{lathe} \tag{4.14}$$

The total amount of lathe and clipper production time allocated to different logs by log source *s*, type *t* and diameter class *d*. It must not exceed the total lathe and clipper time available during period *T*.

B. Dryer

$$\sum_{h=h_1}^{H} DR_h * XMD_h \leq AT_{dryer} \tag{4.15}$$

The total amount of dryer production time allocated to different veneer thicknesses *h* produced from different logs by source *s*, type *l* and diameter class *d*. It must not exceed the total dryer time available during period T.

C. Stringer \ Splicer

$$\sum_{h=h_1}^{H} SR_h * XMS_h \leq AT_{splicer} \tag{4.16}$$

The total amount of stringer \ splicer production time allocated to the upgraded veneer grades from different thicknesses *h*. It must not exceed the total stringer \ splicer time available during period *T*.

D. Glue Spreader

$$\sum_{c=c_1}^{C} \sum_{g=g_1}^{G} GR_{cg} * XMG_{cg} \leq AT_{spreader} \tag{4.17}$$

The total amount of glue spreader production time allocated to different panels by thickness *m* and grade *g* based on the types of corestocks. It must not exceed the total glue spreader time available during period *T*.

E. Hotpress

$$\sum_{m=m_1}^{M} \sum_{g=g_1}^{G} HR_{mg} * XMH_{mg} \leq AT_{hotpress} \tag{4.18}$$

The total amount of hotpress production time allocated to different panels by thickness m and grade g. It must not exceed the total hotpress time available during period T.

F. Sander

$$\sum_{m=m_1}^{M} SDR_m * XMSD_m \leq AT_{sander} \tag{4.19}$$

The total amount of sander production time allocated to different panels by thickness m and grade g. It must not exceed the total sander time available during period T.

V. Market Requirements

A. Veneer Sales

i) Maximum sale forecasted volume

$$\sum_{h=h_1}^{H} \sum_{j=j_1}^{J} XVS_{hj} \leq \sum_{h=h_1}^{H} \sum_{j=j_1}^{J} QV\max_{hj} \tag{4.20}$$

The maximum total amount of veneers by veneer thickness and grouping that is wanted or desired to be sold.

ii) Minimum ordered volume

$$\sum_{h=h_1}^{H} \sum_{j=j_1}^{J} XVS_{hj} \geq \sum_{h=h_1}^{H} \sum_{j=j_1}^{J} QVmin_{hj} \tag{4.21}$$

The minimum total amount of veneers by veneer thickness and grouping required to be sold. If the product is "undesirable", meaning not priced competitively with the other products, it will be equal to the minimum ordered volume.

B. Panel Sales

i) Maximum sale forecasted volume

$$\sum_{m=m_1}^{M} \sum_{g=g_1}^{G} \sum_{o=o_1}^{O} PCF_{mgo} * XP_{mgo} \leq \sum_{m=m_1}^{M} \sum_{g=g_1}^{G} QP_{mg} \tag{4.22}$$

The maximum total amount of panels by thickness and grade wanted or desirable to be sold.

ii) Minimum ordered volume

$$\sum_{m=m_1}^{M} \sum_{g=g_1}^{G} \sum_{o=o_1}^{O} PCF_{mgo} * XP_{mgo} \geq \sum_{m=m_1}^{M} \sum_{g=g_1}^{G} QP_{mg} \tag{4.23}$$

The minimum total amount of panels by thickness and grade wanted or desired to be sold. If the product is "undesirable", it must be equal to the minimum ordered volume.

4.5 Model Structure

The efficacy of the models to respond to the needs of the operation being modelled depends on the model structure. As discussed earlier in Chapter 3, the structure of the model relies heavily on what data had been collected. The quality of the data defines the quality of the model, not only on the problem of risk and uncertainty that can negate utility of the model, but also on final outcome of model structure. As one of the objectives of this study is to develop a general model to address the concept of hierarchical planning (see part 4.8), the structure of the model should be detailed enough to be used in operational planning level. The structure of LOGPLY and VENPLY, therefore, was designed beyond current management needs and outlook on how these models could function in providing a decision-making aid to run the operation. The fundamental unit of analysis is "product grade", in which the contribution of every veneer grade and every panel grade to the profitability of the operation during the planning period (T) can be evaluated. In log resource constraints, "product grade" analysis can be synonymous with log diameter class; thus, the effect of log diameter on the profitability of the business can be properly quantified. The "grade analysis approach" is apparent in the subscript of almost all of the constraints in the series of mathematical equations (Equations 4.1 to 4.23). Decisions are made at the grade level in LOGPLY and VENPLY rather than by thickness level, as are most of veneer and plywood LP models discussed in Chapter 2.

The shorthand notations [Equations (4.1) to (4.23)] are not clear enough to decipher the interrelationships of the constraints and decision variables especially by managers who do not have extensive mathematical backgrounds. For this reason, the block diagram patterned after the detached matrix coefficient shown in Figure 4-3 is presented here to indicate clearly what the overall structure comprises. The diagram represents the components and structure of model in a flowchart type of juxtaposition.

LOGPLY and VENPLY are characterised by a special structured constraint sets often present in large-scale LP models. The special constraint structure consists of a series of independent matrix subsystems that are tied or coupled together by a common set of constraints or variables. The structure of these models, for example in LOGPLY, as shown in Figure 4-3, belongs to this category. The model consists of: (i) staircase structures (e.g. log constraints); (ii) block angular (e.g. constraints on logs to be peeled and veneers to be produced (Figure 3-4); (iii) dual angular (e.g. veneers to be produced constraints and combination of either veneer sales activity, veneer downgrading or layup options (same figure)); and (iv) multicoupled angular which is portrayed by a repeated or nested variable coupling within matrix subsystems as described by Shao (1986), (e.g intermediate product material balance constraint on

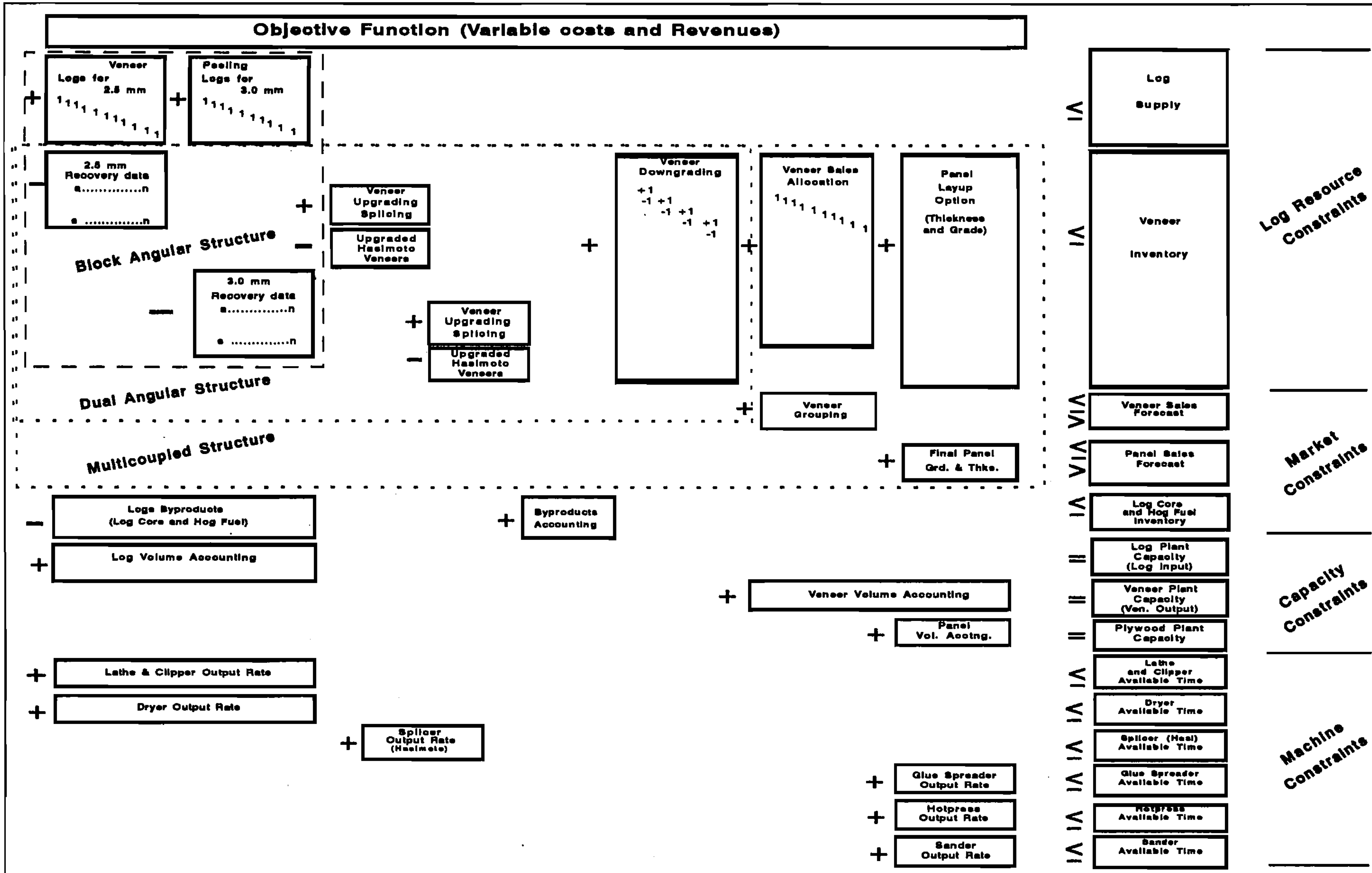


Figure 4-3. General Structure of LOGPLY LP Model

veneers together with market requirement constraints constituting the triple multicoupled structure (same figure)). These types of structure create a computational burden in solving the problem when the size or number of constraint rows increases, as observed in running LOGPLY with present of the panel falldown yield matrix. The panel falldown yield (different grades of panel developed when pressing a certain specific panel grade) matrix determine properly how much of each layup option should be produced to meet market demands and to allow for the amount of falldown. This matrix is excluded in this study because no realistic data could be obtained from the production records to reflect realities. Without the falldown yield matrix, the models still belong to a special constraint structure, as shown in Figure 4-3. However, this special structure also creates opportunities and advantages in addressing areas of operation which have not been exploited before: i) the opportunity to address the concept of soft optimisation or *de novo* programming approach, that is determining through analysis the optimal right-hand-sides (RHS) of some of the constraints which are considered to be unknown (see 4.6.2 for more details); and ii) figuring the "true production cost" and "opportunity cost" not only of final products but also the intermediate products through the dual values. Compactification and decomposition techniques are solution methods to optimise such problems while exploiting the above special structure to solve part of the problem and subsequently solved the whole problem (Shao, 1986). Compactification methods seek to store the overall problem in some efficiently compressed data form by taking advantage of certain structured characteristics of the basis inverse matrix itself (e.g. Lower and Upper (LU) decomposition by Bartels and Golub used by SAS (1985) and recently by Beeline (LP package for spreadsheets used in the study). The model is still treated as one single problem in the method. Decomposition methods, on the other hand, seek to break up the general problem into several smaller subproblems and then coordinate the subproblem solutions in terms of the original problem. Dantzig-Wolfe (1960) decomposition methods and the Rosen (1964) partitioning approach are well-known decomposition methods.

4.6 Model Implementation

4.6.1 Standard Unit Formulation

The numerical implementation of the mathematical models determines how the model should work to obtain a numerical solution for the interpretation and analysis of the results, and establish trends and relationships. The units of measurement must be consistent within each column and so must those across each row. Thus, the A_{ij} act as conversion constants between the rows and columns (Dykstra, 1984). Furthermore, consistency of conversion units among activities is desirable to ease debugging and interpretation of results. As mentioned earlier, LOGPLY and VENPLY have special structures related to the three-stage nature of the problem of veneer and plywood operations, (allocating logs, peeling into veneers and laying the veneer into plywood, while satisfying and optimising the product mix by grade and thickness in their associated low and high selling restrictions). Consistency of units of measurement especially in this particular special structure, is desirable and necessary to interpret the results properly, especially the areas of the associated "opportunity" and "penalty" costs, the dual values of each activity. These dual values can be obtained during the analysis. If no cost coefficient were given before running the models, these duals are supplied, but, if the cost coefficient is given, relative "gain" or "loss" values are supplied. Most of the models studied in veneer and plywood operations, except Seale (1989), were formulated into different units of measurements: logs were in volume, veneers were in surface area and panel in surface area and reconciled to a common panel thickness. These different units of measurements are hard to visualise in an integrated way, and to be reconciled by production and marketing managers. The managers are used to unit volume in their daily transactions (e.g. logs are purchased in unit volume so that veneer and plywood are sold in unit volume rather than surface area). Because of this, the concept of a standard unit of formulation is introduced, with emphasis on a homogeneous standard of measurement that is consistent among variables (e.g. all volumes are in cubic metres and all time is in minutes). All the coefficients are reconciled to only these two units: logs, veneers and plywood are expressed in cubic metres; machine rates are in cubic metres per minute. The advantages of this approach are: (i) avoid confusion on how to relate to the unit of measure from one activity to another during the formulation of the model and interpretation of results; (ii) consistency of conversion units among activities e.g. logs to veneer, veneer to plywood, veneer upgrading and falldown yield downgrading were easily achieved. These activities often led to a discrepancy in results for previous formulations, as logs were in volume, veneers were often measured in surface area, plywood in panels of thinnest or standard panel thickness for the coefficients in the LP model. A third advantage, therefore, was (iii) easy interpretation of results so that a straightforward analysis of the output can be achieved.

4.6.2 Soft Optimisation Approach

All of the veneer and plywood LP models being discussed in Chapter 2 were designed primarily to determine optimal solutions to prespecified problems; that is optimising a given system (traditional LP formulation). However in the real production scene, resources are often not fixed, but can be changed and acquired depending upon their economic value and contribution to the production system. The situation calls for a new approach called soft optimisation or *de novo* programming approach (Zeleny, 1981). This approach recognises that not all constraints are "hard" (fixed quantities to be allocated), but some of the constraints can be assumed to be "soft" and to be determined through analysis. Optimisation of a *given system* (traditional LP formulation where all the constraints are fixed) is certainly different from *design* of an optimal system. The design problem, therefore, is not how to optimise the *given* system with fixed constraints, but rather how to determine the optimal level of some of the *soft* constraints or unknown RHS of the constraints.

Zeleny's (1986) external reconstruction algorithm (ERA) is an example of a *de novo* algorithm that can be used to solve this problem and standard LP problem. The iterative algorithm works through the use of an aggregate constraint which initially consists of: i) all fixed inequality constraints to be reconstructed; ii) all soft inequally constraints to be designed; or iii) any combination of the above. In this algorithm, the aggregate constraint should never include all equality constraints since they are taken as fixed and must be satisfied to achieve feasibility. It takes advantage of working out only the binding constraints first to characterise the optimal solution to the problem and the rest are reconstructed while determing the optimal levels of the soft constraints. In each iteration, the most violated fixed inequality is decoupled from the aggregate constraint and a new LP is solved. The new problem consists of one additional fixed constraint and the revised aggregate constraint. Decoupling and resolving is continued until all the fixed inequalities are satisfied and the optimal levels for the soft constraints are being designed.

To illustrate how the de novo programming can be formulated, consider the mathematical model shown below:

$$Max\ Z = \sum_j c_j x_j \qquad \text{(i)}$$

Subject to

$$\sum_j a_{ij} x_j \le b_i \qquad i = 1,2,\dots,m \qquad \text{(ii)}$$

$$x_j \ge 0 \qquad j = 1,2,\dots,n \qquad \text{(iii)}$$

Assuming that s of m constraints are soft, while the remaing h (h = m - s) constraints (including any equalities) are hard. With this situation, the mathematical model for de novo programming or formulation as simplified and presented by Bare *et al.* (1989) is:

$$Max\ Z = \sum_j c_j x_j$$

Subject to

$$\sum_j a_{ij} x_j \le b_i \qquad \text{(iv)}$$

$$\sum_j (\sum_i a_{ij} p_i) x_j = \sum_i p_i b_i \le B \qquad \text{(v)}$$

$$x_j \ge 0$$

for all $i \in h$ aggregate constraint

where:

p_i = per unit price or cost of a given resource b_i which is to be designed

B = the Budget, the amount of money available for the purchase of scarce resources

The aggregate constraint [Equation (v)] is used to determine the amount of each resource to purchase in order to design the most efficient system. When the contraints are decoupled from the aggregate constraint, they are treated as fixed [moved to Equation (iv)], B is reduced, and another iteration is performed.

LOGPLY and VENPLY were formulated in such away to accommodate this concept of designing an optimal system or soft optimisation aside from the traditional use of optimising suboptimal systems. The log availability constraints are viewed as variables and constraints and subject to design in LOGPLY while in VENPLY the veneer availability constraints are viewed in the same manner, to be designed optimally, if desired. The RHS values of these resources (logs by SED, type and source in LOGPLY and veneers by thickness and grade in VENPLY) constraints can be soft and determined through analysis. However, the exact formulation mentioned above to fomulate an aggregate constraint using unit price or cost p_i of a given resource b_i and budget money B was not exactly followed for the reason of the company's data confidentiality. No figure was given on the budget money for logs but amount of logs to be processed instead. Thus, the log plant capacity constraint (Equation 4.11) for LOGPLY becomes the aggregate constraint and the RHS is used as a budget. The log plant capacity constraint is directly tied or coupled with equations 4.8 (log availability \ procurement matrix which is to be designed) and 4.10. Equation 4.10 (Intermediate product material balance matrix) is coupled with all the constraints in the model (Figure 4-3). In VENPLY, the veneer capacity constraint becomes the aggregate constraint and RHS is the budget.

This approach enhanced the capability of LOGPLY and VENPLY to act as a tool for strategic planning for designing optimal log procurement and veneer production strategies.

4.7 Hierarchical Planning System

LOGPLY and VENPLY are formulated for the purpose of addressing the concept of hierarchical planning. The hierarchal planning concept was conceived from Anthony's hierarchy of managerial decisions (Hax, 1976). They have now become the strategic planning (long-range), tactical planning (medium-range) and operation control (short-term), (Silver and Peterson, 1985). The nature and characteristics of decision problems in hierarchy are shown in Table 4-2.

Table 4-2. Summary of Anthony's Hierarchy Applied to the Production Function

Category of Activity	Strategic	Tactical	Operational
Objectives	Plans for acquisition of resources	Plans for utilization of resources	Detailed execution of schedules
Managerial level	Top	Middle	Low
Time horizon	Long	Medium	Short range
Level of detail	Very aggregated	Aggregated	Very detailed
Degree of uncertainty	High	Medium	Low
Examples of variables under control of management	Products to sell; sizes and locations of facilities; nature of equipment; long-term raw material and energy contracts; labour skills needed; nature of production planning and inventory management decision systems	Operation hours of plants; work force sizes; inventory levels and output rates	What to produce (procure), when, on what machine (from which vendor), in what quantity, and in what order; order processing and followup; material control

Source: Silver and Peterson, 1985.

The main approach in addressing the hierarchical planning system is through the use of a re-usable model structure for all planning levels. One model structure encompassing all aspects of an enterprise is used at all levels with different planning horizons and different variables to be addressed. A one - two year planning period or longer could be used for strategic, three months - six months for tactical and two months - fortnightly planning periods for operational planning. With this approach, a more coherent result of the objectives derived from different planning levels can be achieved. The log procurement strategy in strategic planning properly coordinates, through optimisation, the use of log resources available for production in tactical planning as well as the scheduling aspects of producing the panels in a fortnightly planning period. Figure 4.4 illustrates how the models could function at different planning levels, as explained in the next section.

4.7.1 Strategic Planning

With the use of the *de novo* programming approach, the utility of LOGPLY-S (see Figure 4.4) to address the objective at this planning level, namely the acquisition of resources, has dramatically improved. As explained earlier, the *de novo* programming approach will design an optimal system; thus, an optimal log procurement strategy could be determined. The approach allows one to determine the right log type proportion to procure and the right combination of different veneer thicknesses to be peeled from these logs to satisfy the forecasted product-mix demands. In this way, a more sensible log procurement strategy can be drawn. Furthermore, the profitable product mixes and the different machine capacities to produce the product mixes can be determined. Subsequently, long-range choices concerning production equipment, energy, and labour skills can be evaluated as well.

4.7.2 Tactical Planning

At the tactical planning level, LOGPLY-T and VENPLY-T can be used simultaneously to achieve the same objective of optimising a given system or situation, to allocate the logs available for production and to allocate veneer inventory to the product mix for LOGPLY-T and VENPLY-T, respectively. This approach copes with a lack of recovery data or inaccurate recovery data inputs that are essential to run LOGPLY-T. Running LOGPLY-T with inaccurate recovery data and poorly

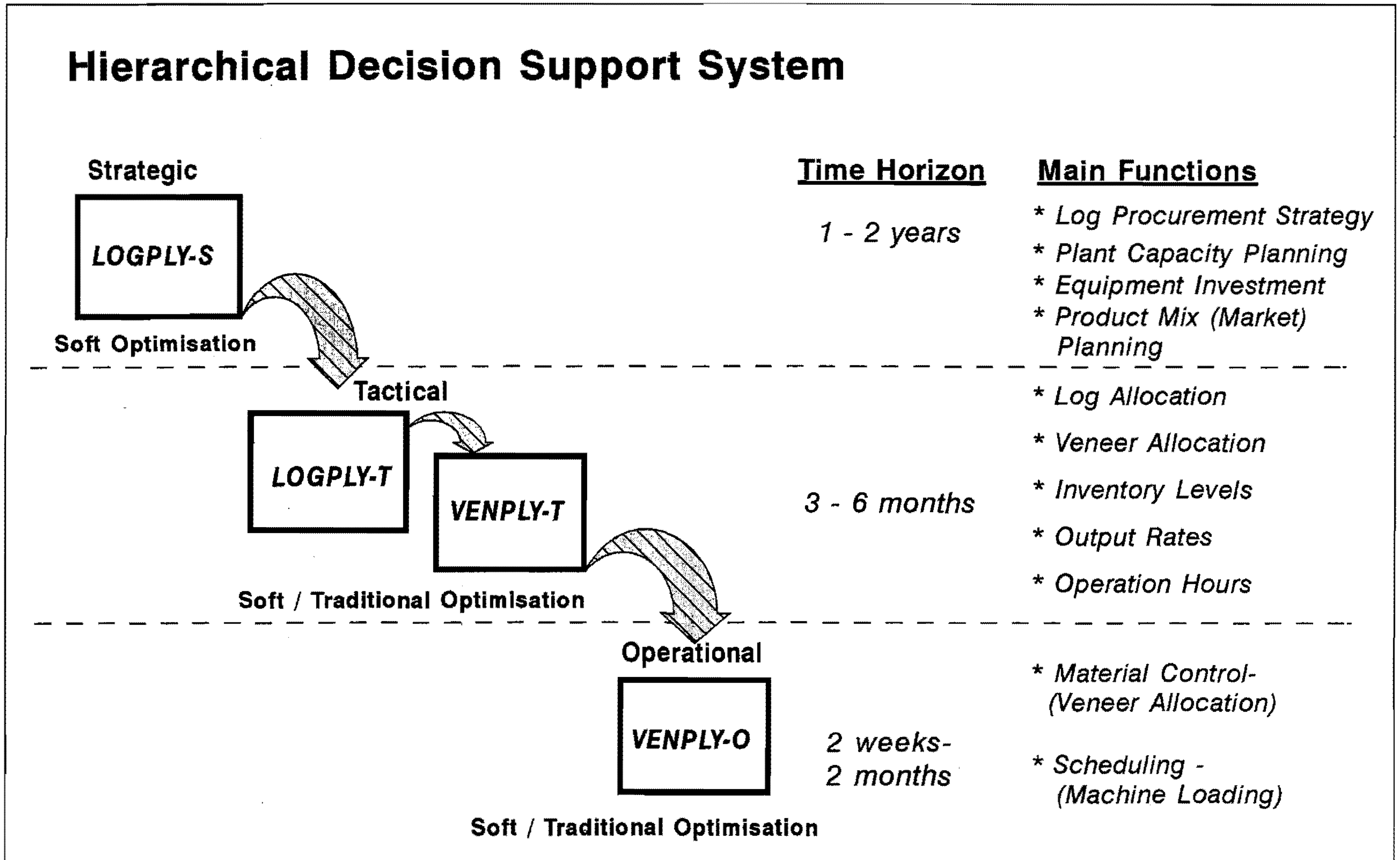


Figure 4-4. The Models and Hierarchical Planning

calibrated recovery figures could lead to a major discrepancy in characterising the conversion of volumes of logs-to-veneers and veneers-to-plywood compared to actual operations. This problem can be overcome, however, using VENPLY-T as a second optimiser to allocate properly the veneer outturn from the actual mix of logs that is available or recommended by LOGPLY-T. Moreover, hours of operation at the plant (number of shifts), work force sizes, inventory levels and output rates including bottlenecks can be determined.

4.7.3 Operational Planning

An this planning level, VENPLY-O provides a quantitative production scheduling tool. Using VENPLY-O in a fortnightly planning horizon will provide better control over material handling and machine-manpower scheduling. Veneer can be properly optimised and allocated to the ordered product mix. The volumes of veneer by thickness and grade for the different panel thickness, grade and layup options can be determined. Furthermore, machine time for every machine centre for each panel thickness, grade and layup option can be determined. Consequently, machine loading from day to day and shift to shift can be properly planned in order that target product mixes can be produced and subsequently delivered in due time. The available machine time for every machine centre can be properly measured and adjusted to meet the desired machine time supplied by the model. However, constraint type of production can be simulated in the model similarly to evaluate the effects of machine bottlenecks in the production.

4.8 Functions of the Models

The models can address the global needs of veneer and plywood operations at different planning levels.

a) ***Log procurement, price, mix and allocation.*** LOGPLY can give managers the ranking of logs by their source, type, diameter class according to their production potential value. The ranking can be used for, (i) competitive log procurement strategy e. g. ordering desirable logs and paying suppliers a premium price, (ii) log price negotiation, and (iii) log swapping strategy between the plywood plant and sawmills. Decisions on log mix proportions can be much clarified. At the tactical planning level, LOGPLY allocates efficiently the available logs by log source, type, diameter class and peel thickness that is needed to produce the product mix.

b) ***Veneer valuation.*** The real value or worth of veneer by grade and thickness in relation to veneer selling price, plywood prices, production costs and other factors can be determined.

c) ***Veneer requirement.*** The exact veneer requirement by grade and thickness to produce the product mix can be easily determined, based on presumed conditions (with or without veneer grading).

d) ***Optimal layups and product mix determination.*** The best layup option to manufacture a specific product is supplied in the solution. The profitability or loss from manufacturing a certain product in relation to the whole product mix can also be determined.

e) ***Evaluation of new products.*** Prices of new products can be drawn from the solution of LP models. The preset prices of new products, moreover, can be properly gauged, calibrated and analysed to see if individual products are worth producing for the market. Prices of the new product can be adjusted, if need be and a subsequent run of the model will determine how the new product or adjusted prices compare with the rest of the products.

f) ***Plant capacity planning.*** Three levels of plant capacities are being addressed in the models, namely; (i) log input capacity, (ii) veneer output capacity and (iii) plywood output capacity to suit the planning, tactical and operational planning needs of both production and marketing operations.

g) ***Machine performance.*** All the pertinent machine centres are included in the model; thus, any bottleneck in the operation can be determined. Using the change-constraints programming approach, the performance of any one machine can be analysed with respect to the profit it contributes to the operation.

h) ***Production scheduling and control.*** Material requirement and machine time for specific production runs can be drawn from the solutions, thus the question on when and how to manufacture the product can be addressed;

i) ***Production and market coordination.*** The concept of market-oriented manufacturing introduced in this study can generate improved coordination between the two operations;

j) ***Marketing.*** Marketing managers can ascertain what products are most profitable to market and what discounts to offer as well as what product mix to market to contribute a greater profitability in the operation; and

k) ***Investment options.*** Log procurement strategies, plant capacity and machine capacities are addressed in the two models. Management can obtain useful insights into where to invest their money in order to have greater profitability for the operation.

This chapter has presented the modelling philosophies adopted to conceptualise and formulate suitable plant models, the general structures of LOGPLY and VENPLY, the potential use of the models in hierarchical planning horizons (strategic, tactical and operational) and how the models can function to address the global needs of veneer and plywood operation. The next chapter deals with the computer model implementation; the database needed to formulate and run operational models in a spreadsheet environment.

Chapter 5

Computer Model Implementation

The usefulness and efficacy of mathematical models such as LOGPLY and VENPLY to characterise production systems and allow them to be analysed and utilised by end-users depend largely on how successfully they can be run on computers. The available database and chosen computer platform determine how successful the model can be implemented in routine practice. The ability to translate the modeller's form, like the series of linear equations formulated and presented in 4.4, into a working model is subject to availability of the necessary representative data to construct and run that working model. The quality and quantity of data, together with the appropriateness of underlying assumptions, are all very important elements to capture in order to reflect effectively the real conditions of any operation being modelled. The chosen computer platform and its environment determine how successfully the models can be to run to obtain desirable solutions in reasonably quick time. In the end, it is the modelling (the model together with its use) that determines the success or failure of the application. The numerical solution in reality reveals and exposes the situation to be analysed. The solution shows, supports and confirms claims that better management can result from mathematical modelling.

The first part of this chapter describes fully in detail the whole database needed to construct a working version of the LOGPLY and VENPLY models on computer. The processing or manufacturing data discussed in Chapter 3, which were needed to structure an efficient model, are one part of the whole database. Methods and suggestions on how to collect these data to characterise the raw material resource, production, processing, and markets, which were not mentioned in Chapter 3, will also be discussed here. The second part of the chapter describes the computer platform and environment in which LOGPLY and VENPLY can be successfully implemented.

5.1 The Database

The database for LOGPLY and VENPLY comprises raw material, production, processing and market data. The potential of the systems or the models to address overall needs of decision-making can be realised only by having a complete set of data in each of these categories. Thus, a complete set of data is necessary to formulate a working model, for without that, no working model would be realised. Continual updating of the database is essential for successful refinement, modification and realisation of real-time implementation of the LOGPLY and VENPLY working computer models.

5.1.1 Resource Data

I. Log Supply and Prices

LOGPLY requires data on the available log supply in cubic metres (m^3) and the cost in dollars per cubic metre ($/$m^3$) according to source, type and SED class of the logs. The current purchasing of peeler logs in New Zealand is done on a weight basis (t) with conversion to volume (m^3) through average population factors; log SED class is not yet a main criterion for purchasing logs, although one has been devised to categorise log quality (see Appendix B for the minimum and maximum small end diameter specifications agreed upon by processors and suppliers). Volume by SED class of the logs from truck loads being delivered could be readily determined. One solution would be to require suppliers to provide SED details of the logs in every truck being delivered. Alternatively, the SED of individual logs could be measured after delivery, as is currently done in plants for monitoring total volume of logs processed. These data can be most useful when formed into frequency distribution tables according to SED class for any chosen planning horizon consistent with the needs to run LOGPLY. No log volume data (by source, type and SED) for the particular mill studies are released here for reasons of confidentiality and no specific proprietary data have been given to serve need of this particular modelling approach other than setting the proportion of unpruned to pruned logs processed on average at sixty to forty percent. For these reasons, the log supply volumes shown in Table 5-1 are distributed equally among SED classes. Regarding the log price or log cost according to SED class, the management can also make use of SED frequency distribution tables to provide proper pricing of logs. However, in this study, the log prices or costs used are the same for all SED classes emanating from a particular source to reflect actual practice. The log prices given by the management used in this study are also shown in Table 5-1.

Table 5-1. Log Supply and Prices

Unpruned Logs		Volume		
	SED class range	Annually		Price
Log Type / Source	(cm)	(m3)	(%)	($/m3)
	35 - 39	4999	7.6	90
	40 - 45	4999	7.6	90
CB	46 - 50	4999	7.6	90
	51 - 62	4999	7.6	90
	Total	**19996**	**30.2**	
	35 - 39	4999	7.6	90
	40 - 45	4999	7.6	90
UP	46 - 50	4999	7.6	90
	51 - 62	5286	8.0	90
	Total	**20283**	**30.6**	
Sub Total	**Unpruned Logs**	**40279**	**60.8**	
Pruned Logs		**Volume**		
	SED class range	**Annually**		**Price**
Log Type / Source	(cm)	**(m3)**	**(%)**	**($/m3)**
	35 - 39	1620	2.4	117
	40 - 45	1620	2.4	117
PP	46 - 50	1620	2.4	117
	51 - 62	1620	2.4	117
	Total	**6480**	**9.8**	
	35 - 39	1620	2.4	120
	40 - 45	1620	2.4	120
TPB	46 - 50	1620	2.4	120
	51 - 62	1620	2.4	120
	Total	**6480**	**9.8**	
	35 - 39	1620	2.4	120
	40 - 45	1620	2.4	120
MP	46 - 50	1620	2.4	120
	51 - 62	1620	2.4	120
	Total	**6480**	**9.8**	
	35 - 39	1620	2.4	120
	40 - 45	1620	2.4	120
RP	46 - 50	1620	2.4	120
	51 - 62	1620	2.4	120
	Total	**6480**	**9.8**	
Sub Total	**Pruned Logs**	**25920**	**39.2**	
Grand Total	**U & P logs**	**66199**	**100**	

II. Veneer Supply / Veneer Inventory

VENPLY requires data on veneer supply by veneer grade and thickness in cubic metres (m^3) and cost in dollars per cubic metre ($/$m^3$). The veneer supply can be easily determined from the veneer inventory records, if available. However, in the particular plant studied here, veneer inventories by grade and thickness were not recorded for the planning horizon, thus precise data are not available. But it is not necessary, to have veneer supply data, since the main emphasis of VENPLY in this study is to act as a complementary model to LOGPLY. Hence, no veneer supply data are needed, especially for demonstrating the soft optimisation or *de novo* programming approach, which was discussed in 4.6.2 and will be demonstrated later in 6.3. Data on veneer supply according to veneer thickness and grade are necessary when using VENPLY to optimise a given system, as are veneer prices or their relative values to allocate utilisation of the existing veneer inventory to best effect. More details on using VENPLY in relation to veneer supply and its cost are given in 6.3, the VENPLY Case Studies.

5.1.2 Production and Processing Data

I. Veneer Recovery Ratio and Veneer Grade Recovery Factor

LOGPLY requires veneer recovery ratio (VRR) and veneer grade recovery factor (VGRF) by veneer thickness, log SED class, type and source in order to structure an efficient resource-oriented LP model, especially in the area of procuring and processing logs according to SED classes. The methods, problems and solutions in gathering these data are fully discussed in 3.4. The relevance of these data should need no recapitulation, but is presented again here to show the exact data needed as part of the whole database for a working model. The VRR and VGRF of logs by source, type, SED class and peel veneer thickness are based on data from the study conducted to structure a resource-oriented LP model that was discussed in Chapter 3. The VRR and VGRF in Chapter 3 are recalculated using 1.2 X 2.4 m dry trimmed veneer dimension instead the dry untrimmed veneer size, since LOGPLY requires net conversion factors from logs to plywood. The VRR and VGRF figures used to run the model are in Table 5-2.

II. Machine Production Rates

The importance of the individual machine production rate in every machine centre by new material category was introduced in Chapter 3 and no further elaboration of the explanation in 3.4 would seem to be required. The machine production rates of the lathe and clipper, dryer, stringer, glue spreader, hotpress and trimsaws and sander and stacker were all derived from time studies outlined in Chapter 3, and as more fully reported in Appendix C. This set of data represents the actual production condition of the plant represented in LOGPLY and VENPLY. These machine rates were measured as an isolated part of the whole process or independently from each other in order to investigate and evaluate fully the potential and limitation of one machine centre relative to another and to the whole operation.

III. Machine Time Availability

LOGPLY and VENPLY require available machine times for every machine centre. The available machine time depends on: (i) the number of days and shifts that the section or machine is operated during the planning horizon; and (ii) percentage of machine utilisation including possible downtime. The machine time needed for every machine centre in LOGPLY and VENPLY is in minutes. The net available

Table 5-2. Veneer Grade Recovery Factor / Recovery Ratios

Log Source/Type	Veneer Thickness (mm)	SED Class Range (cm)	Veneer Grade Recovery Factor (VGRF) (%) A	B	Cp	C	D	Raw Multi's	Recovery Ratios VRR (%)	LCR (%)	HFR (%)
CB (Unpruned)	2.5	35 - 39	0	0	0	28	12	12	51	23	25
		40 - 45	0	0	0	21	20	11	52	18	30
		46 - 50	0	0	1	12	33	7	52	14	33
		51 - 62	0	2	4	14	22	10	52	11	37
	3.0	35 - 39	0	0	6	14	24	15	58	25	17
		40 - 45	0	0	7	23	9	20	59	18	22
		46 - 50	0	0	25	6	17	10	58	13	29
		51 - 62	0	0	5	12	19	24	61	9	30
UP (Unpruned)	2.5	35 - 39	0	0	5	30	9	8	52	22	26
		40 - 45	0	0	4	18	24	10	56	18	26
		46 - 50	0	0	6	23	19	11	59	13	28
		51 - 62	0	0	3	38	9	11	61	12	27
	3.0	35 - 39	0	0	0	27	14	8	49	22	28
		40 - 45	0	0	0	26	17	9	51	18	31
		46 - 50	0	0	5	18	21	7	51	14	35
		51 - 62	0	1	7	12	25	8	53	10	36
PP (Pruned)	2.5	35 - 39	3	3	12	13	4	6	41	24	35
		40 - 45	3	6	15	12	4	10	51	18	31
		46 - 50	3	11	9	14	6	8	51	14	35
		51 - 62	7	8	18	13	6	9	60	11	28
	3.0	35 - 39	4	6	6	20	9	9	53	22	24
		40 - 45	5	6	10	17	9	10	57	23	21
		46 - 50	6	5	5	18	15	9	58	17	25
		51 - 62	7	7	8	11	17	9	60	13	27
TPB (Pruned)	2.5	35 - 39	0	14	15	7	1	10	47	22	31
		40 - 45	1	7	10	12	11	9	49	18	33
		46 - 50	0	3	13	13	10	8	47	13	39
		51 - 62	3	6	8	15	7	10	50	10	40
	3.0	35 - 39	0	5	16	15	5	8	50	23	27
		40 - 45	1	3	13	22	6	5	49	18	33
		46 - 50	0	0	14	19	5	10	48	13	39
		51 - 62	0	0	0	9	27	14	50	11	39
MP (Pruned)	2.5	35 - 39	1	9	8	3	2	16	39	25	36
		40 - 45	1	6	10	7	1	16	41	18	40
		46 - 50	1	7	10	9	2	18	48	17	36
		51 - 62	2	10	11	10	4	19	55	11	34
	3.0	35 - 39	1	9	8	3	2	16	39	25	36
		40 - 45	1	6	10	7	1	16	41	18	40
		46 - 50	1	7	10	9	2	18	48	17	36
		51 - 62	2	10	11	10	4	19	55	11	34
RP (Pruned)	2.5	35 - 39	0	5	20	7	15	5	51	25	24
		40 - 45	0	13	15	16	7	8	61	17	23
		46 - 50	0	10	12	15	8	9	55	14	32
		51 - 60	0	0	16	15	14	10	56	11	33
	3.0	35 - 39	0	5	20	7	15	5	51	25	24
		40 - 45	0	13	15	16	7	8	61	17	23
		46 - 50	0	10	12	15	8	9	55	14	32
		51 - 62	0	0	16	15	14	10	56	11	33

Note:

VRR - Veneer Recovery Ratio
LCR - Log Core Ratio
HFR - Hog Fuel Ratio

machine time excludes downtime, work-breaks, etc. Commercial managers may have difficulty in grasping the concept and relevance of obtaining such detailed data, that can, as occurred in this study, result in no net available machine time being made available. These machine available times for the modelling here were based upon a total log input volume of 66 199 m^3 and product mix volume of 36 423 m^3. The simulated machine times used in the study are realistic indications of possible machine time utilisation the management has at its disposal, as shown in Table 5-3.

IV. Plant Capacities

The plant capacities are important data required for running LOGPLY and VENPLY models without which information the LP problems formulated could not be solved. They provide the means for characterising the flexibility that is necessary to meet what managers might wish to achieve in planning. They are also needed to identify options where managers can see that more data should be made available, and where more precise and greater control over the operation is needed in order to reflect reality better. The plant capacities in terms of log input, veneer and plywood and plywood are shown in Table 5-4.

V. Product Mix and Product Layup Options

The product mix and its layup options are the main elements needed to formulate veneer and plywood LP models. Without them the models would not exist. Great effort should be expended to identify fully the product mix and to explore every possibility how these products should be manufactured according to layup options. Technical consideration and practicalities should be one of the criteria. For instance, a layup of A-MXB-D-C-D-MXB-B is one possible layup for a 7 ply construction, but in

Table 5-3. Available (Needed) Machine Time

Machine Centre	Net Machine Time		Machine Utilisation @ 100 % Utilisation @2 shifts	@ 100 % Utilisation @3 shifts	@ 80 % Utilisation @2 shifts	@ 80 % Utilisation @3 shifts
	(min)	(h)	(days)	(days)	(days)	(days)
Lathe & Clipper	218013	3634	227	151	273	182
Dryer	207528	3459	216	144	259	173
Stringer (Hasimoto)	332736	5546	347	231	416	277
Glue Spreader	317811	5297	331	221	397	265
Hotpress & Trimsaws	207950	3466	217	144	260	173
Sander & Stacker	249030	4150	259	173	311	208

Note: Values are simulated from the log input volume using LOGPLY.
A shift is equal to 8 hours.

Table 5-4. Plant Capacities

Capacity	Volume (m3)
Log Input	66199
Veneer and Plywood	36423
Plywood	36423

reality it is hard to implement in the actual production run; the stringed corestocks (e.g. MXB) as crossbands and full sheet corestock (e.g. C) as a core would not be a likely combination, since crossbands and cores are basically coming from the same materials scheduled for corestocks in any given production run. Furthermore, feeding these two types of corestock simultaneously or side by side will create a problem in accommodating them into the glue spreader. Implementing an approach of using types of corestocks simultaneously would lower the productivity rate of the glue spreader more than using only stringed corestocks (see different rates of glue spreader in Appendix C). Thus, the aforementioned layup options should not be included as a possible product option. The product mix and layup options used for LOGPLY and VENPLY modelling are shown in Table 5-5. All of these are feasible, not notional options.

5.1.3 Market Data

I. Market Demand

Production, market demand, and sale-forecasted data are terms used synonymously in this study in order to highlight the relevance of LOGPLY and VENPLY to act as market-oriented manufacturing models. Although the market demand can be predicted using econometric models or time series analysis or in whatever way managers prefer, the most important requirement is that they should reflect reality. The production and market demand volumes should always be synchronised and updated in every planning horizon in order to realise a real-time modelling capability for LOGPLY and VENPLY. The annual production and marketing plan of the product mix used in this study are shown in Table 5-6 based on the percentage of the individual panel production in 1991 actual production of the plant

Table 5-5. Product Mix and Their Layup Options

Panel Thickness : 7.5 mm

Grade		Option	Veneer Thickness (mm)
A/B	1	A-MXB-B	2.5
	2	A-C-B	2.5
A/C	1	A-MXB-C	2.5
	2	A-C-C	2.5
A/C	1	A-Cp-C	2.5
(Clearline)	2	A-HCp-C	2.5
B/B	1	B-MXB-B	2.5
	2	B-C-B	2.5
B/D	1	B-MXB-D	2.5
	2	B-C-D	2.5
CP/D	1	Cp-MXB-D	2.5
	2	Cp-C-D	2.5
	3	HCp-MXB-D	2.5
	4	HCp-C-D	2.5
C/D	1	C-MXB-D	2.5
	2	C-C-D	2.5

Panel Thickness : 9.0 mm

Grade		Option	Veneer Thickness (mm)
A/B	1	A-MXB-B	3.0
	2	A-C-B	3.0
A/C	1	A-MXB-C	3.0
	2	A-C-C	3.0
A/C	1	A-Cp-C	3.0
(Clearline)	2	A-HCp-C	3.0
B/B	1	B-MXB-B	3.0
	2	B-C-B	3.0
B/D	1	B-MXB-D	3.0
	2	B-C-D	3.0
CP/D	1	Cp-MXB-D	3.0
	2	Cp-C-D	3.0
	3	HCp-MXB-D	3.0
	4	HCp-C-D	3.0
C/C	1	C-MXB-C	3.0
	2	C-C-C	3.0
C/D	1	C-MXB-D	3.0
	2	C-C-D	3.0

Panel Thickness : 12.5 mm

Grade		Option	Veneer Thickness (mm)
A/B	1	A-MXB-C-MXB-B	2.5
	2	A-MXB-D-MXB-B	2.5
	3	A-C-C-C-B	2.5
	4	A-C-D-C-B	2.5
A/C	1	A-MXB-C-MXB-C	2.5
	2	A-MXB-D-MXB-C	2.5
	3	A-C-C-C-C	2.5
	4	A-C-D-C-C	2.5
A/C	1	A-Cp-C-Cp-C	2.5
(Clearline)	2	A-Cp-D-Cp-C	2.5
	3	A-HCp-C-HCp-C	2.5
	4	A-HCp-D-HCp-C	2.5
B/B	1	B-MXB-C-MXB-B	2.5
	2	B-MXB-D-MXB-B	2.5
	3	B-C-C-C-B	2.5
	4	B-C-D-C-B	2.5
B/D	1	B-MXB-C-MXB-D	2.5
	2	B-MXB-D-MXB-D	2.5
B/D	1	B-C-C-C-D	2.5
	2	B-C-D-C-D	2.5
CP/D	1	Cp-MXB-C-MXB-D	2.5
	2	Cp-MXB-D-MXB-D	2.5
	3	Cp-C-C-C-D	2.5
	4	Cp-C-D-C-D	2.5
	5	HCp-MXB-C-MXB-D	2.5
	6	HCp-MXB-D-MXB-D	2.5
	7	HCp-C-C-C-D	2.5
	8	HCp-C-D-C-D	2.5
C/D	1	C-MXB-D-MXB-D	2.5
	2	C-MXB-C-MXB-D	2.5
	3	C-C-C-C-D	2.5
	4	C-C-D-C-D	2.5

Panel Thickness : 15.0 mm

Grade		Option	Veneer Thickness (mm)
A/C	1	A-MXB-C-MXB-C	3.0
	2	A-MXB-D-MXB-C	3.0
	3	A-C-C-C-C	3.0
	4	A-C-D-C-C	3.0
B/B	1	B-MXB-C-MXB-B	3.0
	2	B-MXB-D-MXB-B	3.0
	3	B-C-C-C-B	3.0
	4	B-C-D-C-B	3.0
B/D	1	B-MXB-C-MXB-D	3.0
	2	B-MXB-D-MXB-D	3.0
	3	B-C-C-C-D	3.0
	4	B-C-D-C-D	3.0
Cp/D	1	Cp-MXB-C-MXB-D	3.0
	2	Cp-MXB-D-MXB-D	3.0
	3	Cp-C-C-C-D	3.0
	4	Cp-C-D-C-D	3.0
	5	HCp-MXB-C-MXB-D	3.0
	6	HCp-MXB-D-MXB-D	3.0
	7	HCp-C-C-C-D	3.0
	8	HCp-C-D-C-D	3.0
C/D	1	C-MXB-C-MXB-D	3.0
	2	C-MXB-D-MXB-D	3.0
	3	C-C-C-C-D	3.0
	4	C-C-D-C-D	3.0

Panel Thickness : 17.5 mm

Grade		Option	Veneer Thickness
A/B	1	A-MXB-D-MXB-D-MXB-B	2.5
	2	A-MXB-C-MXB-C-MXB-B	2.5
	3	A-C-C-C-C-C-B	2.5
	4	A-C-D-C-D-C-B	2.5
A/C	1	A-MXB-D-MXB-D-MXB-C	2.5
	2	A-MXB-C-MXB-C-MXB-C	2.5
	3	A-C-C-C-C-C-C	2.5
	4	A-C-D-C-D-C-C	2.5
B/B	1	B-MXB-D-MXB-D-MXB-B	2.5
	2	B-MXB-C-MXB-C-MXB-B	2.5
	3	B-C-C-C-C-C-B	2.5
	4	B-C-D-C-D-C-B	2.5
B/D	1	B-MXB-D-MXB-D-MXB-D	2.5
	2	B-MXB-C-MXB-C-MXB-D	2.5
	3	B-C-D-C-D-C-D	2.5
	4	B-C-C-C-C-C-D	2.5
Cp/D	1	Cp-MXB-D-MXB-D-MXB-D	2.5
	2	Cp-MXB-C-MXB-C-MXB-D	2.5
	3	Cp-C-C-C-C-C-D	2.5
	4	Cp-C-D-C-D-C-D	2.5
	5	HCp-MXB-D-MXB-D-MXB-D	2.5
	6	HCp-MXB-C-MXB-C-MXB-D	2.5
	7	HCp-C-C-C-C-C-D	2.5
	8	HCp-C-D-C-D-C-D	2.5
C/D	1	C-MXB-D-MXB-D-MXB-D	2.5
	2	C-MXB-C-MXB-C-MXB-D	2.5
	3	C-C-C-C-C-C-D	2.5
	4	C-C-D-C-D-C-D	2.5

Panel Thickness :21.0 mm

Grade		Option	Veneer Thickness (mm)
A/B	1	A-MXB-D-MXB-D-MXB-B	3.0
	2	A-MXB-C-MXB-C-MXB-B	3.0
	3	A-C-C-C-C-C-B	3.0
	4	A-C-D-C-D-C-B	3.0
A/C	1	A-MXB-D-MXB-D-MXB-C	3.0
	2	A-MXB-C-MXB-C-MXB-C	3.0
	3	A-C-C-C-C-C-C	3.0
	4	A-C-D-C-D-C-C	3.0
B/B	1	B-MXB-D-MXB-D-MXB-B	3.0
	2	B-MXB-C-MXB-C-MXB-B	3.0
	3	B-C-C-C-C-C-B	3.0
	4	B-C-D-C-D-C-B	3.0
B/D	1	B-MXB-D-MXB-D-MXB-D	3.0
	2	B-MXB-C-MXB-C-MXB-D	3.0
	3	B-C-D-C-D-C-D	3.0
	4	B-C-C-C-C-C-D	3.0
Cp/D	1	Cp-MXB-D-MXB-D-MXB-D	3.0
	2	Cp-MXB-C-MXB-C-MXB-D	3.0
	3	Cp-C-C-C-C-C-D	3.0
	4	Cp-C-D-C-D-C-D	3.0
	5	HCp-MXB-D-MXB-D-MXB-D	3.0
	6	HCp-MXB-C-MXB-C-MXB-D	3.0
	7	HCp-C-C-C-C-C-D	3.0
	8	HCp-C-D-C-D-C-D	3.0
C/D	1	C-MXB-D-MXB-D-MXB-D	3.0
	2	C-MXB-C-MXB-C-MXB-D	3.0
	3	C-C-C-C-C-C-D	3.0
	4	C-C-D-C-D-C-D	3.0

Table 5-6. Notional Annual Panel Production and Marketing Plan

Panel Thickness: 7.5 mm

Panel Grade	Volume (m3)	Percent Production (%)	Percent Grade Prdn. (%)	Remarks
A/B	113	0.31	1.6	
A/C	188	0.52	2.6	
A/C	188	0.52	2.6	Clearline
B/B	188	0.52	2.6	
B/D	150	0.41	2.1	
HCp/D & Cp/D	2327	6.39	32.6	W/ Hasimoto Faced Cp
C/D	3975	10.91	55.8	
Thickness Total Prdn.	7129	19.57	100.0	

Panel Thickness: 9.0 mm

Panel Grade	Volume (m3)	Percent Production (%)	Percent Grade Prdn. (%)	Remarks
A/B	75	0.21	2.8	
A/C	56	0.15	2.1	
A/C	56	0.15	2.1	Clearline
B/B	56	0.15	2.1	
B/D	75	0.21	2.8	
HCp/D & Cp/D	150	0.41	5.7	W/ Hasimoto Faced Cp
C/C	1162	3.19	44.0	
C/D	1013	2.78	38.3	
Thickness Total Prdn.	2643	7.26	100.0	

Panel Thickness: 12.5 mm

Panel Grade	Volume (m3)	Percent Production (%)	Percent Grade Prdn. (%)	Remarks
A/B	113	0.31	1.2	
A/C	94	0.26	1.0	
A/C	94	0.26	1.0	Clearline
B/B	675	1.85	7.2	
B/D	1125	3.09	12.0	
HCp/D & Cp/D	5250	14.41	56.0	W/ Hasimoto Faced Cp
C/D	2025	5.56	21.6	
Thickness Total Prdn.	9376	25.74	100.0	

Panel Thickness: 15.0 mm

Panel Grade	Volume (m3)	Percent Production (%)	Percent Grade Prdn. (%)	Remarks
A/C	75	0.21	2.2	
B/B	413	1.13	12.2	
B/D	825	2.27	24.4	
HCp/D & Cp/D	1313	3.60	38.9	W/ Hasimoto Faced Cp
C/D	750	2.06	22.2	
Thickness Total Prdn.	3376	9.27	100.0	

Panel Thickness: 17.5 mm

Panel Grade	Volume (m3)	Percent Production (%)	Percent Grade Prdn. (%)	Remarks
A/B	188	0.52	1.7	
A/C	188	0.52	1.7	
B/B	188	0.52	1.7	
B/D	750	2.06	6.7	
HCp/D & Cp/D	8250	22.65	73.3	W/ Hasimoto Faced Cp
C/D	1688	4.63	15.0	
Thickness Total Prdn.	11252	30.89	100.0	

Panel Thickness: 21.0 mm

Panel Grade	Volume (m3)	Percent Production (%)	Percent Grade Prdn. (%)	Remarks
A/B	75	0.21	2.8	
A/C	133	0.37	5.0	
B/B	150	0.41	5.7	
B/D	188	0.51	7.1	
HCp/D & Cp/D	1313	3.60	49.6	W/ Hasimoto Faced Cp
C/D	788	2.16	29.8	
Thickness Total Prdn.	2647	7.27	100.0	

Annual Total Production	**36423**	**cubic metres**	

as supplied by the CHH management. The percentage distribution of the product mix is also similar to the previous production records of the plant under the Fletcher Wood Panels management. The exact volume is notional but not the percentage of individual panels in the whole production. Thus, this set of data reflects production and marketing realities.

II. Product Prices

LOGPLY and VENPLY models require individual product prices as a necessary component. They determine the relative profitability of one product relative to another and of one production option. For more detailed discussion see Chapter 6. The prices for the specified product mix used in this study are shown in Table 5-7, as supplied by CHH management. They are most likely the export prices of the products: hence, they are lower than the prevailing domestic prices.

5.2 Computer Implementation

5.2.1 The PC Platform

Since the creation in March 1981 of the first IBM PC computer with Intel 8088 CPU, 64 Kb RAM, two 160 Kb floppy disks together with the MS-DOS 1.0 by Microsoft or PC-DOS 1.0 by IBM operating system (the disk operating system is a joint venture by Microsoft and IBM) (Somerson, 1988), IBM compatibles or clones from desktop to palmtop have been sprouting like mushrooms everywhere around the world except in the eastern block countries. The success can be attributed to the following reasons: i) software developers jumped on to the "IBM bandwagon" by developing applications and computer languages including the translation of the most

Table 5-7. Notional Product Mix Prices

Panel Thickness: 7.5 mm

Panel	Export Ave. Price		Remarks
Grade	($/m3)	($/Panel)	
A/B	876.00	18.92	
A/C	760.00	16.42	
A/C	880.00	19.01	Clearline
B/B	1280.00	27.65	
B/D	780.00	16.85	
Cp/D	728.00	15.72	
HCp/D	728.00	15.72	Hasimoto Faced Cp
C/D	670.00	14.47	

Panel Thickness: 9.0 mm

Panel	Export Ave. Price		Remarks
Grade	($/m3)	($/Panel)	
A/B	1150.00	29.81	
A/C	929.00	24.08	
A/C	1050.00	27.22	Clearline
B/B	1100.00	28.51	
B/D	800.00	20.74	
Cp/D	750.00	19.44	
HCp/D	750.00	19.44	Hasimoto Faced Cp
C/C	706.00	18.30	
C/D	706.00	18.30	

Panel Thickness: 12.5 mm

Panel	Export Ave. Price		Remarks
Grade	($/m3)	($/Panel)	
A/B	880.00	31.68	
A/C	850.00	30.60	
A/C	1080.00	38.88	Clearline
B/B	760.00	27.36	2S
B/D	690.00	24.84	
B/D	820.00	29.52	T&G
Cp/D	660.00	23.76	
HCp/D	660.00	23.76	Hasimoto Faced Cp
C/D	685.00	24.66	

Panel Thickness: 15.0 mm

Panel	Export Ave. Price		Remarks
Grade	($/m3)	($/Panel)	
A/C	950.00	41.04	
B/B	650.00	28.08	2S
B/D	650.00	28.08	
Cp/D	630.00	27.22	
HCp/D	630.00	27.22	Hasimoto Faced Cp
C/D	630.00	27.22	

Panel Thickness: 17.5 mm

Panel	Export Ave. Price		Remarks
Grade	($/m3)	($/Panel)	
A/C	950.00	47.88	
B/B	800.00	40.32	
B/D	710.00	35.78	
Cp/D	610.00	30.74	
HCp/D	610.00	30.74	Hasimoto Faced Cp
C/D	674.00	33.97	

Panel Thickness: 21.0 mm

Panel	Export Ave. Price		Remarks
Grade	($/m3)	($/Panel)	
A/B	1000.00	60.48	
A/C	950.00	57.46	
B/B	700.00	42.34	
B/D	680.00	41.13	
Cp/D	660.00	39.92	
HCp/D	660.00	39.92	Hasimoto Faced Cp
C/D	650.00	39.31	

Veneer and Byproducts Prices

Item	
	($/m3)
A & B Veneers (2.5 mm)	600
A & B Veneers (3.0 mm)	600
Log Cores	131
Hog Fuel	40

commonly used mainframe language, FORTRAN and creation of new ones e.g. BASIC, Pascal, C and object oriented languages (e.g. C++); ii) the text file format or ASCII format can be easily outputted on PC's and can be ported easily back and forth between mainframes and minis; iii) fast and timely development of compatible BIOS (basic input and output system) by Phoenix Technology and AMI (American Megatrends Inc.) that can read and write IBM PC formats which are sold to computer manufacturers; iv) extensive research and development for compatible CPUs and coprocessors, e.g. the V20 by Nippon Electronic Corporation (NEC) is another alternative replacement for Intel 8088, recently Advanced Micro Devices (AMD) 80386 and 80486 series and Cyrix 80486 compete for the slots for Intel 80386 and 80486 series, and for coprocessors, IIT and Weitek produce compatible and affordable coprocessors; and vi) hundreds of computer component developers and manufacturers who made innovations from power supply to BUS architecture to make them powerful, faster, smaller and cheaper in months rather years.

PC operating systems have evolved dramatically from a character-based user interface, DOS, to a graphical user interface (GUI), Windows and OS/2. Three computer company giants IBM, Microsoft and Digital Research are fighting for supremacy and dominance in operating systems over this single platform. IBM launched OS/2 version 2. Microsoft keeps on improving MS-DOS now version 5.0 (jointly owned by IBM) and Windows 3.1, beta versions (test version) of MS-DOS 6.0 (due to be released in March 1993) and Windows NT are on evaluation and testing and soon to be released. The Digital Research DOS (DR-DOS) version 6.0 is gaining acceptance on account of their having more utilities, e.g. disk compression for doubling disk space capacity. MS-DOS version 6 is also going in the direction of adding more ulitities. These operating systems are designed to exploit fully the 32 bit processors, 80386 and 80486 machines, but, provision has been made for backward compatibility with software designed for an 8 bit (8088 and 8086) and 16 bit (80286) computers. This means that all old PC software and application will definitely run in these operating systems as well. The new breed of operating systems has also broken the "640 Kb barrier" and 32 Mb hard disk partition, enabling users to access more available memories and hard disk space of the machine. The 80286 machine has a maximum memory of 16 megabytes (Mb) but 80386 and 80486 ones have 4 gigabytes (Gb) of memory, and one fixed disk partition on the hard disk can be made up to 128 Mb (MS-DOS Version 5 Reference Guide, 1992). With this development, all mainframe programs, theoretically speaking, can now be run on PC's if they are translated to that environment.

Aside from the cheaper, powerful hardware and operating systems, it is now no longer unduly expensive to purchase applications and languages equipped with programming utilities in computer shops. The GUI environment (Windows and OS/2) has made a huge improvement in the use of object oriented programming to cater for the needs of specialised developers, by providing a visual programming language and utilities like Object Vision by Borland and Visual Basic by Microsoft. Nevertheless, a big issue has arisen on the future of the computer industry: will it concentrate on software (Rappaport and Halevi, 1991) or hardware development (Burton *et al.*, 1991). A most probable outcome of these challenges will be the fast development of an open system, a computer platform that runs all programs designed for the Mac, PC and Unix. With these facts, there is no doubt that the PC is the most preferred platform to implement applications including the models, LOGPLY and VENPLY due to PC's computing power, acceptability, availability, affordability and portability.

5.2.2. LP Implementation in PC

Recently, computer programming and researchers in different disciplines have joined the PC bandwagon in implementing their applications on the PC environment. Management science \ operations research (MS\OR) and the forestry management sector are no exception to this new trend in exploring every possibility a PC can offer for their analytical needs. Mainframe developers on the other hand, have now translated most of their applications to embrace the new era of computing. For example, the LP systems designed formerly for the mainframe (e.g. Mathematical Programming System in PC (MPS-PC - the *de facto* standard for specifying LP problems), MINOS, and LINDO) are all available in PC platform (Sharda, 1988). There is much evidence that LP models developed for and applied to several fields have been translated successfully and routinely run in PC. Sharda *et al.* (1984, 1986, 1988) made an extensive review of the performance of advanced PC LP systems. However, those LP systems did not reflect the current status of a PC platform just a few short years later, especially on the 80386 and 80486 machines. Even though the authors used an 80286 machine to review these systems in 1986, LP systems reviewed were designed primarily for 8086 machines, the support of a 8087 math co-processor was deemed to be the main criterion of an advanced LP system. Later Sharda mentioned more improved LP packages, capable of addressing the extended and expanded memories of the 80286 machines. Advances in LP packages are: i) spreadsheet-based (e.g. VINO, What's Best and XA); ii) model generation systems (e.g. GAMS\MINOS and XPRESS-LP); and iii) a system that permits expression form, capable of symbolic substitution at run time (e.g. XA). Almost all of these LP packages use the revised simplex algorithm that capitalise on the inverse matrix manipulation. Nevertheless, they concluded that the PC software performed well overall in medium-size LP models. Recently, these LP packages have been upgraded to exploit the 32-bit computer and its co-processor to solve large-scale LP models. Two powerful forest planning and management LP models are being implemented on the PC platform and widely accepted by forest industry: i) Forest Planning (FORPLAN) in the United States; and (ii) Forest-Oriented Linear Programming Interpreter (FOLPI) in New Zealand.

FORPLAN is a tool used primarily by the USDA Forest Service for analyzing economic, and production tradeoffs in the development of comprehensive forest plans. It was originally designed for a UNISYS mainframe , but has been translated to use NDP FORTRAN for a 386 PC system and now called RMS (Rocky Mountain Station) FORPLAN (Ager *et al.*, 1991). The LP package used to solve the problem is LINDO/386, a version designed for 80386 and 80486 machines which is capable of accessing the extended and expanded (beyond 640 Kb) memories of the computer. The size (rows and column) of models ranges from 2 000 x 30 000 to 8 000 x 40 000. The solution time is from 1 to 48 hours. The greatest advantage of migrating RMS FORPLAN into the PC environment has been that the system now resides on the same platform as other software [(word processor, spreadsheets and relational databases) and in house (Forest Service) packages] used to build data sets and interpret solutions.

FOLPI is a linear programming-based forestry planning system that can be used by forest managers without a detailed knowledge of Linear Programming (LP). It was developed by Garcia at the New Zealand Forest Research Institute (Garcia, 1984). The programs were first written in BASIC, with a few in FORTRAN and Pascal. It was run on an ICL 2980 computer and later on a VAX 780. The LP packages used were LP 2980 for ICL 2980 and GAMS\MINOS for the VAX 780. Recently, it was converted to the PC platform, on 80386 and 80486 machines with 4 Mb memory together with EXtended Application (XA) and C-Whiz as LP packages to solve the problem (FOLPI 386 User Guide version 1.40, 1992). It is widely used by private corporations in New Zealand such as NZ Forest Products, Tasman Forestry, Carter Holt Harvey and the Forestry Corporation of New Zealand to address their planning needs. There is no mention of the restriction on the size of system that can be run in terms of rows and columns, but variables, constraints and entries. The limits are: i) maximum number of periods should not exceed 70; ii) maximum number of crop types is 70; iii) maximum number of age classes is 70; iv) maximum number of products in products file is 13; v) maximum number of entries in thinning file is 350; vi) maximum number of products in thinning file is 6; and vii) maximum number of products in plant file is 6. Individual limits can be presumed to be a function of the memory available on a specific computer. FOLPI runs faster in C-Whiz than XA but needs more free disk space for temporary files or swap files. The output is in ASCII or text format, but FOLPI has utilities that can convert text to spreadsheet format (WKS) and vice-versa.

The widespread use of these two powerful LP models in forestry prove that a PC platform can be equal to a mainframe in terms of power in implementing large-scale LP models. The PC has, moreover, the further advantage of mobility (for 386 and 486 notebooks) and computing in colour. This implies that the PC platform is undoubtedly, the best platform to implement LOGPLY and VENPLY LP models to provide a portable and real-time decision support tool for veneer and plywood operation managers.

5.2.3. The Spreadsheet and Modelling

Every serious PC and Mac user nowadays uses the spreadsheet. The copy and move commands are very popular and make the spreadsheet appealing to every kind of user. Sales and acceptance of spreadsheets is legendary. They have become an indispensable software tool for managers in financial management applications, e.g. cash flows and balance sheets. But it is not always clear to users what spreadsheets comprise and how they can be used most effectively. Lotus (1986) defined a spreadsheet as a two-dimensional (now three-dimensional) matrix of displayable interrelated storage areas called cells. The cell can contain information in the form of data items, a formula, or text which are interrelated one to the other. Aside from the content of individual cells, the spreadsheet can employ global factors which affect the entire matrix, including global format settings. The essential feature of any spreadsheet program is its ability to create and resolve relationships among cells. It also has user-friendly (menu-driven), inbuilt mathematical and statistical functions, graphics, etc. The third generation spreadsheets are now equipped with file linking, 3 dimensional capabilities and external database access to improve consolidation and how to manage information from different sources. It also breaks the 640 Kb barrier, accessing more memory allocation which leads to the creation of thousands of cells that can be linked not only in two (row and column) but now three dimensions, (page) (Apiki *et al.*, 1990). Previously a spreadsheet could be considered to be the electronic equivalent of a ledger sheet, but now these third generation spreadsheets are big stacks of ledger sheets with file linking ability. Spreadsheet power has been further enhanced by boosting analytical capabilities in the packages, the function lists for which keep growing: goal seekers and matrix manipulation help with problem solving; scenario managers help store inputs to models, making 'what-if' analysis easier (Aitken, 1992). Enhanced macro languages add power by allowing automation of repetitive tasks and by letting developers build applications. Publishing capabilities including scalable fonts, a combination of printable and displayable graphs together with worksheet, slide show and drawing utilities are present in today's spreadsheets. Moreover, third party software developers have developed and are continuing to develop add-ons with additional features that use the spreadsheet environment both as input and output avenue starting from printing (e.g. Allways, Sideways), databases (@Base, Paradox link in Quattro Pro 3.0), Monte Carlo simulation (@RISK), LP packages (Beeline, What's Best, VINO and XA). These spreadsheet features and add-on or add-in software make the spreadsheet a suitable environment to be used for modelling. Modelling veneer and plywood operations is no exception.

After Bodily (1986) suggested possible uses and extensions of the spreadsheet environment for developing applications such as decision tree analysis, risk analysis simulation, optimisation, statistical analysis, etc.. Several other practical implementions using spreadsheets have been reported, especially in production, planning and control. The spreadsheet is heavily used for simulation purposes with its trial-and error approach, because of its speed in recalculating that allows many alternative solutions to be tried and evaluated. Thus, with a systematic approach to generating and examining alternative solutions, the final solution developed from the spreadsheet analysis is likely to be near optimal. Spreadsheet software has been upgraded to accommodate risk analysis simulation by providing the @IF function, @RAND, random number generation for Monte Carlo simulation, linear regression and to extend statistical tools (e.g. simple factorial analysis in Excel 4.0), to name a few. Modelling using spreadsheets has been used in the following areas.

I. Production Planning and Control

A. Aggregate Production Planning In demonstrating the concept of the learning curve to develop realistic aggregate plans that exploit the potential for cost reduction through learning curve effects (Dileepan and Ettkin, 1988).

B. Capacity/Inventory Planning In: (i) developing a time-phased order-point (TPOP) using lot-for-lot policy inventory planning model (Peek and Blackstone, 1987); and (ii) determining what capacity and inventory levels are required to support a specific master production scheduling in the welding industry (Parekh, 1990).

C. Forecasting Winter's method, or triple exponential smoothing forecasting technique for short-range planning was illustrated using spreadsheet (Theise, 1990).

D. Marketing A market segmentation modelling was employed in sporting goods manufacture to design a marketing mix for a new product that would yield the greatest profit (Winter, 1989).

E. Simulation Modelling A study of: (i) fixed-timed simulation for forklift usage to compare a rental plan against a purchase plan for a new forklift; (ii) variable-time model, a simulation of replacement policies of drill bits for a drill press (Cornwell and Modianos, 1990); and (iii) Monte Carlo simulation model, a). a model for an aggregate planning application (Armacost *et al.*, 1990), b). simulating warehouse cost (Canella and Schuster, 1987), to determe the least-cost warehouse location based on transportation, warehouse, and inventory cost considerations.

F. Scheduling (i) Scheduling a job-shop type of operation, to evaluate alternative schedules by simply calculating and displaying graphically the finish times for a given job shop schedule (Pendegraft, 1987). (ii) Deterministic spreadsheet simulation model for production scheduling in a lumpy demand environment (Schuster and Finch, 1990), which provides an effective solution to the problem of managing inventory levels and production scheduling when demand is very lumpy. (iii) Production planning and master scheduling (Hong and Maleyeff, 1987), a spreadsheet-based planning system which replaces the manual planning processes in semiconductor manufacturing and the structure of the master scheduling developed enables decision making to be interactive and intuitive for medium-to-long-range planning problem.

G. Materials Management Safety stock calculations and order quantity trade-offs and relationships (Coleman, 1987), the application deals with the safety stock standard deviations, safety factors, forecasts and lead-time values, among other numbers, as well as "what-if" questions.

II. Forestry

A. Growth and Yield Modelling Diameter distribution growth and yield simulation model for Caribbean pine (*Pinus caribaea* var *hodurensis*) was developed and implemented in spreadsheet form to predict stand average values in conjunction with the existing stem volume and taper equations, and to derive stand and stock tables that allows disaggregation of diameter classes into log types (Villanueva, 1992).

B. Equipment Replacement Modelling Optimal equipment replacement model for harvesting equipment (Ogweno, 1988).

C. Harvest Scheduling Modelling Leefers (1991) and Villanueva (1992) have illustrated the use of spreadsheet to formulate harvest scheduling models. The models were not solely implemented in spreadsheet but with a spreadsheet LP package add-on. Detailed discussion of this topic is given the next section.

D. Wood Utilisation Modelling Process simulation using spreadsheet on pulp and paper manufacture have been conducted and demonstrated by the works of Wells *et al.* (1986) and Orr (1987). In sawmilling, Mendoza *et al.* (1991) developed a prototype log allocation model using the built-in linear programming in Quattro Pro. The model will address the daily or weekly needs of log merchandising and meeting the material requirement of hardwood lumber production. The built-in LP module is limited to 256 combinations of variables and constraints (Quattro Pro 3.0 manual) and hard to manipulate to suit serious application such as the implementation of LOGPLY and VENPLY due to its multicoupled structures, number of constraints and variables.

5.2.4 Linear Programming and Spreadsheet

Problem formulation, matrix description and generation, optimisation and report writing are four phases of preparing LP models to be made operational on a standard LP package to derive numerical solutions suited to situation modelled. Two unavoidable tasks in operational implementation on LP model are; i) the translation of LP model from the modeller's form to algorithmic form; and ii) report writing. The translation can be done through matrix generators and\or modelling languages to produce a transitional or immediate form to facilitate translation to an algorithm's form (Fourer, 1983). Report writing is converting back from the algorthmic form to outputting various tables and graphs that can be readily understood by people. Although the second task is as problematical as the first, virtually every matrix-generator system has an associated report writer system. In recent years, the economics of computing in general and of linear programming in particular have favoured modelling languages, even for forestry applications. FOLPI originally implemented on a mainframe, but now on PC using modelling languages, GAMS

(General Algebraic Modelling System) (Fourer, 1983) and recently in XA (EXtended Application) (Sharda, 1988). They are modelling languages which incorporate symbolic indexing and symbolic substitution at run time, so that they can conveniently represent fairly large models. An alternative that circumverts matrix generation and report writing in a complicated modelling language is to use spreadsheets and spreadsheet add-on LP packages. Medium-sized LP models can be efficiently implemented, run and used routinely as decision support systems in spreadsheet and add-on LP packages (e.g. Beeline, Whats-Best). The model size of 8 193 x 256 (rows and columns) of a standard spreadsheet such as Quattro Pro ver 3.0, Lotus 1-2-3 ver 2.0) or 1 024 x 2 000 can be implemented in the spreadsheet. The spreadsheet is used as an interface between the model and the LP algorithm, as an input and output facility. It provides better communication between the modeller and the LP algorithm.

Optimisation in the spreadsheet is done as follows: i) the formulated LP model in the spreadsheet is saved in standard spreadsheet format (wks or wk1); ii) the format is read by another program and converted into algorithmic form; iii) it is then solved with the LP algorithm and output in algorithmic format; iv) the algorithmic format is read and rewritten to the original spreadsheet worksheet with the solution; and iv) the worksheet is retrieved in the spreadsheet environment. No optimisation is done in the spreadsheet, but only on the LP package, which acts like a subroutine in a conventional computer program.

Spreadsheet and spreadsheet LP add-on packages have already been used in forest harvesting modelling. Leefers (1992), for example, implemented three harvesting models; i) a simulation model using the spreadsheet alone; ii) optimisation using the spreadsheet and LP add-on package, What's Best; and iii) simulation and optimisation using the spreadsheet, Monte Carlo simulation add-on package, @RISK and LP add-on package, What's Best. Villanueva (1992) also implemented harvest scheduling using spreadsheets and the spreadsheet LP add-on package, called Beeline. Both found that the spreadsheet environment and add-on LP packages did indeed provide a better environment for implementing their modelling needs.

Implementing LOGPLY and VENPLY on a spreadsheet environment has many advantages: i) working with cumbersome details of matrix generator or modelling languages that create working LOGPLY and VENPLY models to produce results and desirable output (e.g. tables and graphs) can be totally eliminated; ii) models can be created in tabular or matrix form, whichever is the modeller's preference; iii) the models can be easily modified (e.g. new constraints can be accommodated and new objectives can be substituted) at will; iv) they can be easily linked with other planning models (e.g. inventory program); v) the models can provide instantaneous solution to the need or problem, thus, allowing a real-time decision support system be developed; vi) superb graphics are now available on spreadsheets which provide ease in communicating results; vi) the models constructed in the spreadsheet have a better chance of being adopted and revised to cater for changing managerial needs.

5.2.5 The Working Model

LOGPLY and VENPLY are implemented in Quattro Pro 3.0 spreadsheet and Beeline, a spreadsheet LP add-on package developed by Ashley Software in conjunction with the Department of Management at the University of Canterbury. The Beeline interface and the commands used to construct a spreadsheet LP model were developed using macros. Beeline, like any other spreadsheet LP add-on package, could be used in conjunction with all the commercial available spreadsheets (e.g. Quattro Pro, Lotus 1-2-3, VP Planner, EXCEL, etc.). It offers sophisticated commands that professional LP programmers want from a basic declaration of the objective function, constraints, dual values (reduced cost and shadow prices), sensitivity ranges to MPS output format if desired. Beeline uses the revised simplex algorithm and the latest version uses LU decomposition (Beeline User Manual). The latest version can access the EMMS (expanded memory management system) or memories beyond the 640 Kb of a computer. Beeline comes in two versions, with and without math co-processor. The Beeline version used in this study has neither the EMMS capability nor math co-processor, but this did not restrict the size of the model nor the level of detail, which can be a problem as mentioned earlier. Efficient model formulation of the two models was achieved by using fewer formulae and not using the most abused function, @SUM in LP model construction. A version with EMMS is highly recommended in future implementation and modification of LOGPLY and VENPLY to allow easier formulation and faster run times.

The schematic diagram on how LOGPLY and VENPLY should be efficiently implemented is given in Figure 5-1. The diagram explains the importance of 3-D or linked worksheets in the formulation and development of an input facility, solving the LP model and developing the required outputs in terms of tables and graphs. At this point, LOGPLY and VENPLY are still on one worksheet formulation. The inputs, the LP model, LP solution and simulated outputs from the LP solution (e.g. log percentages, etc.) are contained in one worksheet. Formulating all the desired output in a template on the same worksheet that has to be submitted to Beeline will not produce an algorithmic form: thus, no LP problem will be solved. At this stage, implementation on one worksheet is easy to use from the modeller's point of view, but, if the system is to be adopted by managers and the desired output are to be

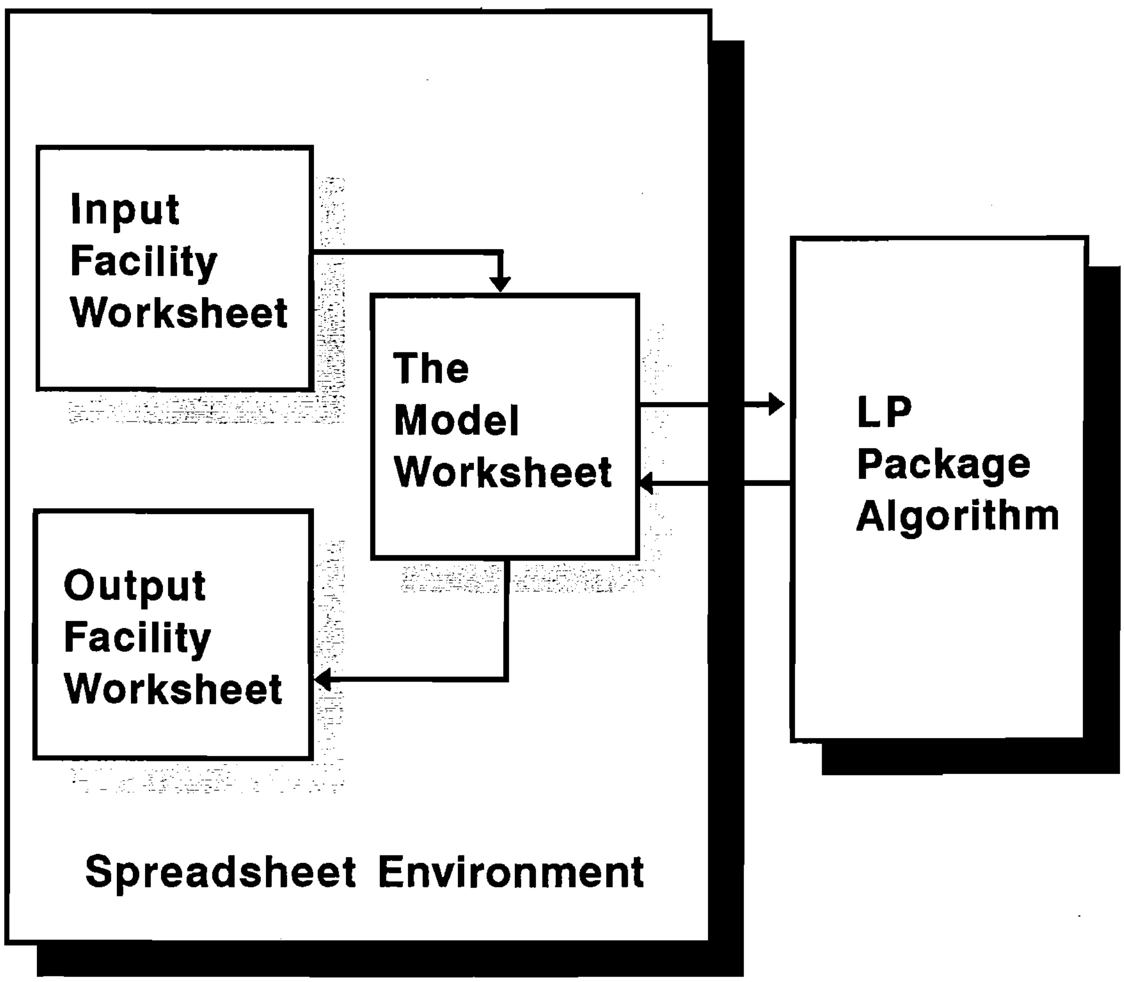


Figure 5-1. Schematic Diagram for the Implementation of LOGPLY \ VENPLY.

finalised to suit managers' preferences, implementation as outlined on the schematic diagram, Figure 5-1 should improve routine use.

I. The Input

Inputting and modifying the data for LOGPLY and VENPLY can be done on different window panes as shown in Figure 5-2. At this stage of development of the models, the input window panes for LOGPLY are properly constructed and working, but the user-friendliness of the system is not yet fully customised to cater for the needs of a non-spreadsheet user to use it routinely. However, the present state does not prohibit the use of this system to analyse veneer and plywood operations, as will be illustrated later in Chapter 6. The input window panes consist of: i) log volume and prices by source, type and SED classes; ii) minimum and maximum product volume by type and thickness; and available machine time by machine centres.

II. The Output

To answer the global needs of decision-making in veneer and plywood operations, LOGPLY output, for example, will consist of the following tables and graphs; i) revenue by product type, grade and thickness; ii) log cost; iii) log volume proportions by source, type, SED class and veneer thickness; iv) log allocation by source; v)product volume and value by panel thickness and grade; v) log ranking and shadow prices; vi) veneer allocation by panel grade; vii) veneer allocation by panel grade; viii) optimal layup option by panel grade; ix) veneer downgrading by veneer grade in different panel thicknesses; x) machine time allocations by section and machine centre; xi) lathe and clipper machine allocation by SED class; xii) dryer time allocation by SED class and veneer thickness; xiii) stringer time allocation by veneer thickness and type of corestocks; xiv) glue spreader time allocation by panel

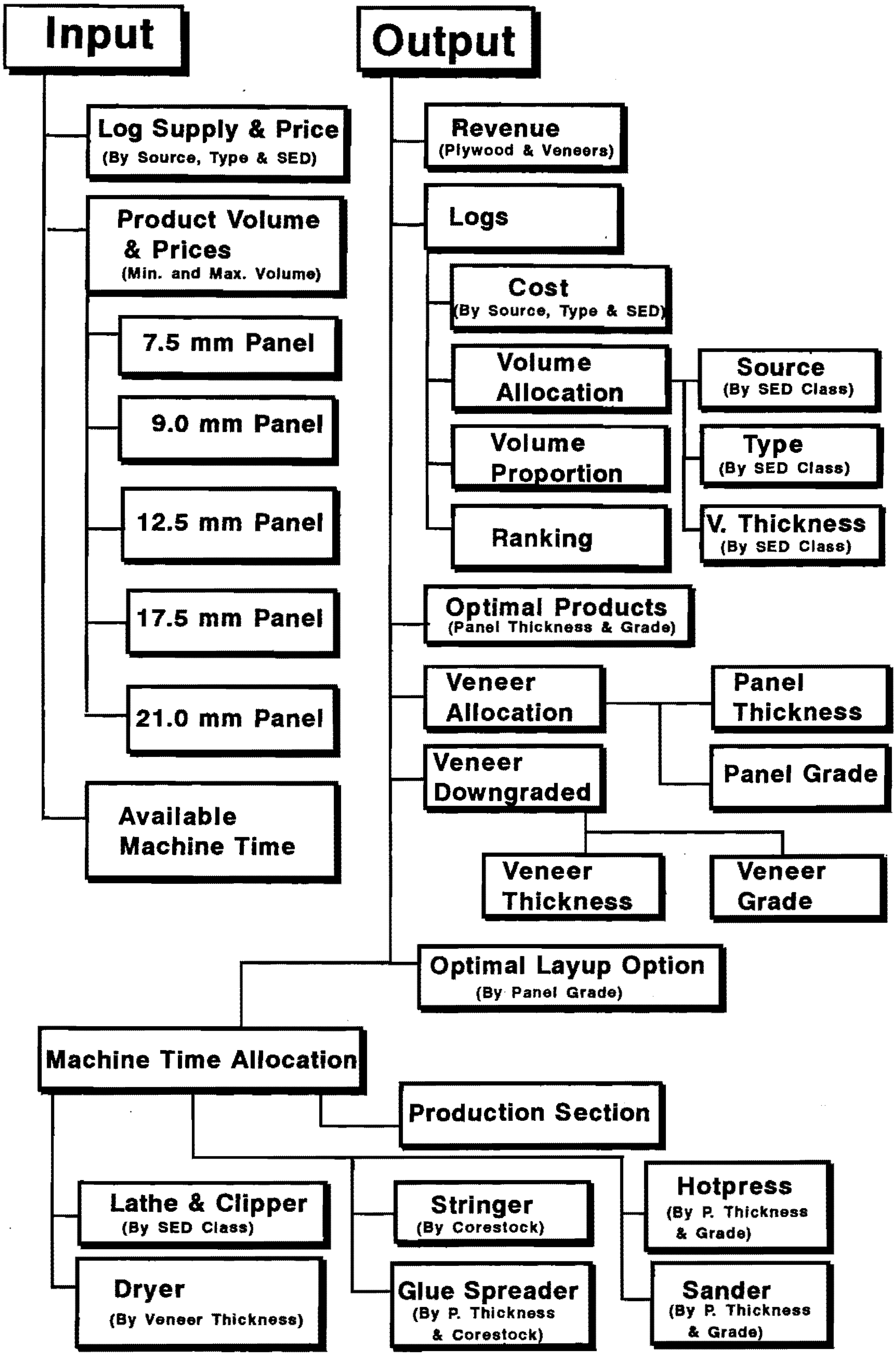


Figure 5-2. Menu Structure of LOGPLY

thickness and type of corestock; xv) hotpress time allocation by panel thickness and panel grade; and xvi) sander time allocation by panel thickness and grade, as shown Figure 5-2. The details of these outputs are fully discussed and presented in Chapter 6.

The next chapter explains and clarifies the use of LOGPLY and VENPLY as resource-oriented, production\manufacturing-oriented and market-oriented optimisation and simulation models to address the overall decision-making needs of veneer and plywood operations.

Chapter 6

Using LOGPLY and VENPLY: The Case Studies

This chapter outlines and analyses the capabilities of LOGPLY and VENPLY to provide systems which address a comprehensive set of decision-making needs in veneer and plywood operations. Although the veneer and plywood operations considered here refer to a softwood processing plant, the applicability of these models to hardwood operations would most likely be similar, while the modelling applications themselves would probably be less complex. Thus, concepts and ideas presented here should apply to any kind of veneer and plywood operation. The most important element in the research is the provision of insights that could be gained to add a new dimension and perspective on how to manage veneer and plywood operations generally and to make them more profitable.

Aside from the classic problem of optimising the gross revenue of a veneer and plywood operation within a given planning horizon, the importance and inter-relationships of the raw material resource (log resource), production capacities (machine centres) and markets to the profitability of the business are fully analysed and discussed here in detail to show and confirm the claim that better management techniques can result from mathematical modelling. This modelling analysis follows a systems approach wherein the operation is viewed as a system of interacting components, rather than as relatively isolated and independent entities. Five case studies using LOGPLY and four case studies using VENPLY have been selected and presented here to describe and characterise the real environment for veneer and plywood operations.

The first part of this chapter describes the different LOGPLY case studies, their basic assumptions and differences. The second part discusses the results obtained from running the 5 LOGPLY case studies in terms of gross revenue, starting from log inputs down the line as far as machine time allocation for the last machine centre, the sander. The third part describes the 4 VENPLY case studies and results of runs of these to show the importance of VENPLY as a model that is complementary to LOGPLY, especially in the areas of better veneer allocation without downgrading.

6.1 The LOGPLY Case Studies

The basic LOGPLY model is created with the database described in Chapter 5: it has 212 decision variables and 153 constraints for Case 1. The time horizon used is one year; thus it is most suited for strategic planning of a year's plant operation. However, as mentioned in preceding chapters, the structure of the models has been designed in detail deliberately to accommodate three levels of hierarchical planning. Therefore, the principles and concepts drawn from the case studies should also pertain to the tactical and operation planning levels in which the risk and uncertainty are minimal. The right-hand-side (RHS) values of the models reflect the individuality of the case scenarios; hence, they may be considered either *hard* (i.e.

fixed or given) or *soft* depending on the specifics from case to case. Thus, the number of constraints will vary from case to case.

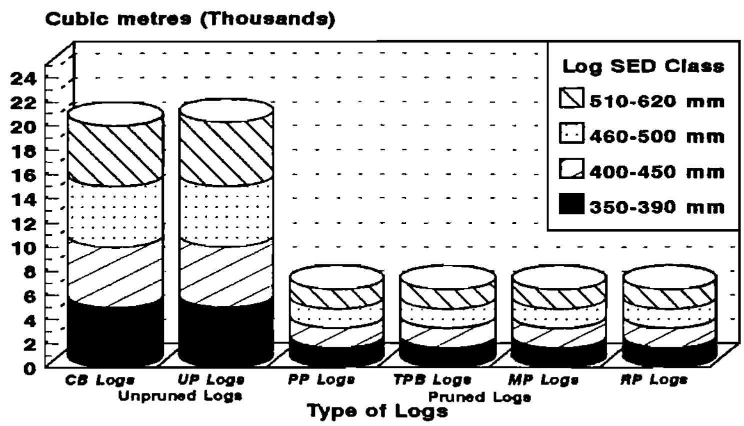
6.1.1 Case 1: Optimising a Given System

This case illustrates the traditional concept of optimisation using LOGPLY, where all constraints are collectively treated as fixed or given. The log resource available and to be allocated is fixed at 66 199 cubic metres, sixty percent (60%) unpruned logs and forty percent (40%) pruned, equally divided among the log suppliers and SED class ranges as shown in Figure 6-1.A. The available machine time for different machine centres was determined through simulation by running the model to ensure that all the logs can be processed and the desired product mix is manufactured. The result of this simulation run determines the machine time for the different machine centres shown in Figure 6-1.B. This represents the available production time of the different machine centres based on actual machine rates determined in the time studies as explained in Chapter 3. The production\market plan for the product mix by panel thickness and grade is shown in Figure 6-1.C. This is both the maximum sale-forecasted volume and the minimum ordered volume assumed for this case. In other words, the model produces the exact amount of panel products by thickness and grade that satisfies the maximum and minimum volumes for the market. The total panel volume to be manufactured is 36 423 cubic metres.

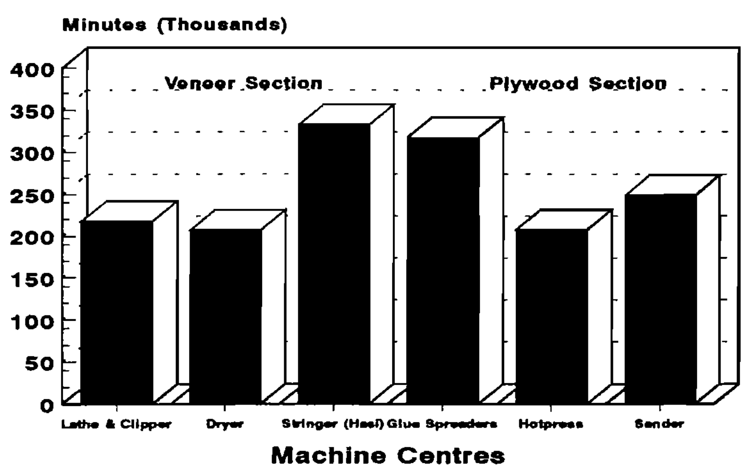
6.1.2 Case 2: Designing an Optimal System

This case demonstrates the soft optimisation approach to designing an optimal system as discussed in 4.6.2. The problem used in this case is basically the same as in Case 1. Instead of assuming a fixed distribution of log inputs as shown in Figure

A. Log Resource (Log Supply e.g. Case 1)



B. Production Scenario (Available Machine Time)



C. Market Scenario (Planned Plywood Volume e.g. Case 1)

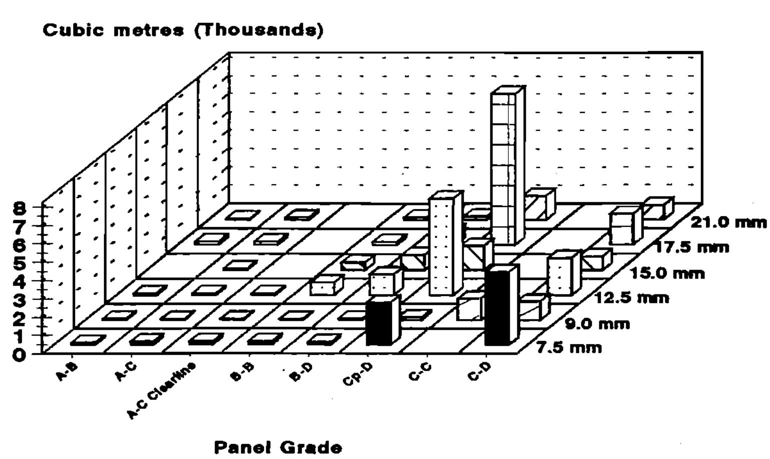


Figure 6-1. LOGPLY Case 1 Main Assumptions.

6-1.A, however, the kind and amount of logs available for peeling are assumed to be flexible and can be chosen independently. The optimal volume of log by log source, log type, SED class and peel thickness has to be determined. There is no restriction on log type proportions. The total log volume can either be equal to or less than the log supply available in Case 1, 66 199 cubic metres. The amount of machine time available for each machine centre is the same as in Case 1, as well as the product mix that is manufactured. The total panel volume to be produced is equal, therefore, to 36 423 cubic metres.

6.1.3 Case 3: Optimising a Given System with Market Demand Variation

This case is very similar to Case 1, the classic problem of optimising a given system. The log type proportion is still 60:40 (unpruned : pruned) and equally distributed among the different log sources and SED class ranges. The total log volume to be allocated is still 66 199 cubic metres. The available machine time by machine centre to be allocated is the same as in Case 1. However, the main difference in this from Case 1 is the market condition: the product mix has a maximum sale-forecasted volume and minimum ordered volume. The maximum sale-forecasted volume by panel thickness and grade is fifty percent (50%) more than the product mix in case 1 except for 21 mm panel which is fixed at the level of the production\market plan. The minimum ordered volume by panel thickness and grade is fifty percent (50%) less than the product mix of Case 1. The potential of the individual panel product by thickness and grade to be manufactured to its limits depends on its profitability as a result of its price, available veneer materials from the peeled logs and relative ease of manufacturing them or, in other words, a wise allocation of machine time. The total panel volume to be manufactured is set at 36 423 cubic metres.

6.1.4 Case 4: Designing an Optimal System with Product and Market Variations

This case is also concerned with designing an optimal system. The log input availability is again flexible and can be designed as in Case 2. The optimal log volume by log source, log type, SED class and veneer peel thickness is to be determined. No log type proportion constraint is imposed. The total log volume to be procured is still less than or equal to 66 199 cubic metres. The machine time availability by machine centre is the same as in Case 1. The main difference from the rest of the case studies presented is the introduction of a new class of product, A & B veneers as additional products. The model allows marketing of A & B veneers if profitable. This means that, if the model determines that A or B veneers are profitable products at a given price ($600 per cubic metre) in the market place, rather than using them for layup material in A face or B face panels or, after satisfying the layup requirements of the profitable quantities of A and B face panels, then the model should so allocate. No restriction on the amount of A & B veneer to be produced is imposed in this case. This case study also evaluates the potential for processing pruned logs at a given price for the profitable production of A & B veneer products at the set price. Aside from the new veneer products, maximum forecasted sale volume and minimum ordered volume are the same as in Case 3. The total panel volume to be produced would again not exceed 36 423 cubic metres.

6.1.5 Case 5: Designing for the Ideal System

This case study examines the potential to design an ideal system for the set environment. It evaluates fully the potential to capitalise on log resource, production equipment and marketable individual product. This case allows investigation of the effects of production capacity and efficiency and it can be viewed as a typical example of strategic planning in the plywood industry for the following reasons: a) log procurement strategy for buying the right logs; and b) existing machine capacities can be properly refined and gauged according to needs. Additional capacities can be properly planned either by hiring additional manpower for another shift or by purchasing additional equipment to meet perceived needs. In order to achieve this, the log input availability as well as the machine time availability are assumed to be flexible and able to be set at chosen levels. The total log volume to be procured is still equal to or less than 66 199 cubic metres. The product mix is the same as in Case 4, that is: A & B veneer are products assumed to be able to be sold in unlimited quantities in the market place if they are profitable, up to the maximum forecasted sale volume and minimum ordered volume used in Cases 3 and 4. There is no restriction on the total panel volume to be manufactured.

6.2 Results and Discussion LOGPLY Case Studies

6.2.1 Revenue and Log Cost

Based on the LP runs for the five LOGPLY case studies, the net revenues for Cases 1, 2, 3, 4 and 5 are; $20.26 M, $21.31 M, $20.98 M, $23.0 M and $29.03 M, respectively. There is an increase in net revenue over Case 1 in all 4 other cases, shown also in Figure 6-2.A. $ 1.04 M was realised by designing an optimal system

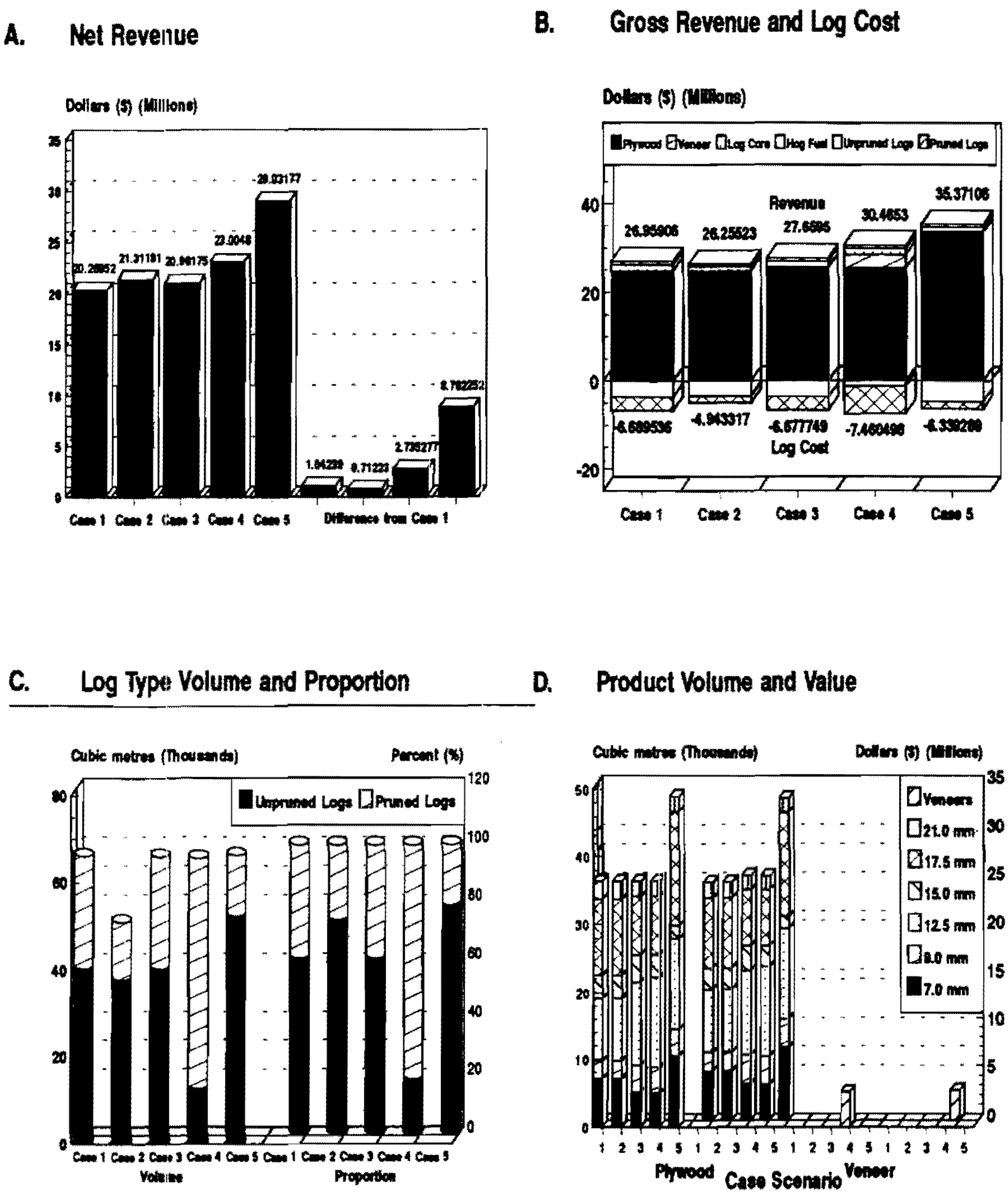


Figure 6-2. Summary of Results in 5 LOGPLY Case Studies.

over optimising a given system (Cases 1 and 2) or selecting the right logs for the production *per se*. $ 0.71 M was attributed to the effect of market situation (Cases 1 and 3). $ 1.67 M was gained from the combined effect of a new product (A & B veneers) and markets (Cases 2 and 4). Six million dollars was realised, mainly as a result of the effect on unlimited available machine time or unconstrainted production conditions and selecting the right logs for the production (Cases 4 and 5). $ 8.76 M was realised as result of unlimited available machine time, the right proportion of logs and the right volume combination of the product mix (Cases 1 and 5).

There is no base case, moreover, to represent the actual scenario for the plant since Case 1 is already an optimised case, and so comparisons are concerned with potentialities and not with shortfalls in actual policies. Nevertheless, the log allocation for Case 1, which depends on the veneer peel thickness and panel layup option selected to produce the set product mix has been optimised and a the net revenue of $ 20.26 M so obtained. This sum could well exceed that of the average annual production from an actual operation. Thus, the actual realisation using LOGPLY can go beyond the revenues presented in the different cases and on the effects of comparing one case to another. It should also be noted that the market conditions applied in the case studies are quite tight because of the imposition of the maximum and minimum market requirements to simulate a tight market scenario. Eliminating a minimum market requirement could easily result in further gains of two million dollars in net revenue. The net revenue of the actual operation is not revealed here in the interests of preserving commercial confidentiality.

It is interesting to note that the revenue derived from plywood products alone in Cases 1 to 4 did not differ greatly even though the product mix market conditions are slightly different from each other (Figure 6-2-B). The exception is Case 5, which represents an entirely different situation. The plywood product revenue are; $2.469 M, $2.469 M, $2.540 M and $2.529 M for Cases 1, 2, 3 and 4 respectively. The sale of the byproducts improved the case revenue somewhat. In Case 3, the revenue from A & B veneers adds $3.13 M to the total. However, the log cost makes a difference in total net revenue for all the case studies presented, as shown in Figure 6-2.B. The log cost for Cases 1, 2, 3, 4, 5 are; $6.68 M, $4.94 M, $6.67 M, $7.46 M and $6.33 M, respectively. Cases 1 and 2, for example, have identical product mix volumes in terms of thickness and grade (Figure 6-2-D) as one of the conditions for these cases, equal to the planned production/marketing plan, yet the log cost for Case 2 is 1.746 dollars million less than the log cost for Case 1. This is attributed to the selection of logs, Case 2 processed a lesser volume of logs (Figure 6-2.C) but ones more appropriate to produce the right amount and combination of veneers that result in a product mix through the selection of less costly logs, usually unpruned ones. Thus, log procurement activity is an important factor in making veneer and plywood a more profitable operation.

The next section deals more fully with this topic of log allocation and procurement, as this aspect applies to all the other cases too. However, this particular analysis has clearly illustrated that the veneer and plywood plant operation should not be fully fed with 100 percent pruned logs as claimed by the 1992 New Zealand Forest Industries Strategy Study (Edgar *et al.*, 1992) and as can be seen in Figure 6-2.C.

6.2.2 Log Allocation and Procurement

As discussed in the previous chapters, log allocation and procurement in this study focus more on to log source, log type, log SED class and veneer peel thickness. Figure 6-2.C identifies the log volume and proportion of each log type in different cases. Evidently, the log type proportion selected depends on log veneer outturn and the veneer grade requirement to produce the corresponding product mixes (Figure 6-2.D). Cases 2 and 4 required more unpruned logs, 74.2 percent and 78.9 percent, respectively to the total log consumption than the management expectation of just 60 percent. These cases could be the most likely approach to adopt to enchance profitability of veneer and plywood operations in New Zealand, since the competing Asian market requires more Cp-D grade or lower grades for packing and for low cost housing material. Most of the Asian uses for plywood are predominantly for construction purposes. The strength of panels is a more important factor than the aesthetic value of the product in structural designs and building construction. However, the potential to process more pruned logs would always depend on the price level of A & B veneers, as shown in results of Case 4 and 5 (Figure 6-2.D) as well the right price and demands for high grade faced (A & B) panels. In Case 4, A & B veneers are relatively profitable to produce but not in Case 5 as a result of the conditions imposed in these case studies. In Case 4, the total volume of panel is fixed at 36 423 cubic metres while in Case 5, there is no restriction on the total volume of panels to be manufactured. Thus, the overall analysis reveals that production of A & B veneers at $600 per cubic metres is a less profitable option when there is a demand for A and B faced panels, as in Case 5.

The most suitable log allocation to obtain the required amounts of veneer peel thickness can also be determined from use of this model. Log allocation according to log type, SED class and veneer peel thickness in the different cases is shown in Figure 6-3. Log allocation according to peel thickness depends, of course, on the required product mix to be produced. In the cases which are designed optimally, namely 2, 4 and 5 (Figure 6-3.C, E & F), it is apparent that the SED class 510-620

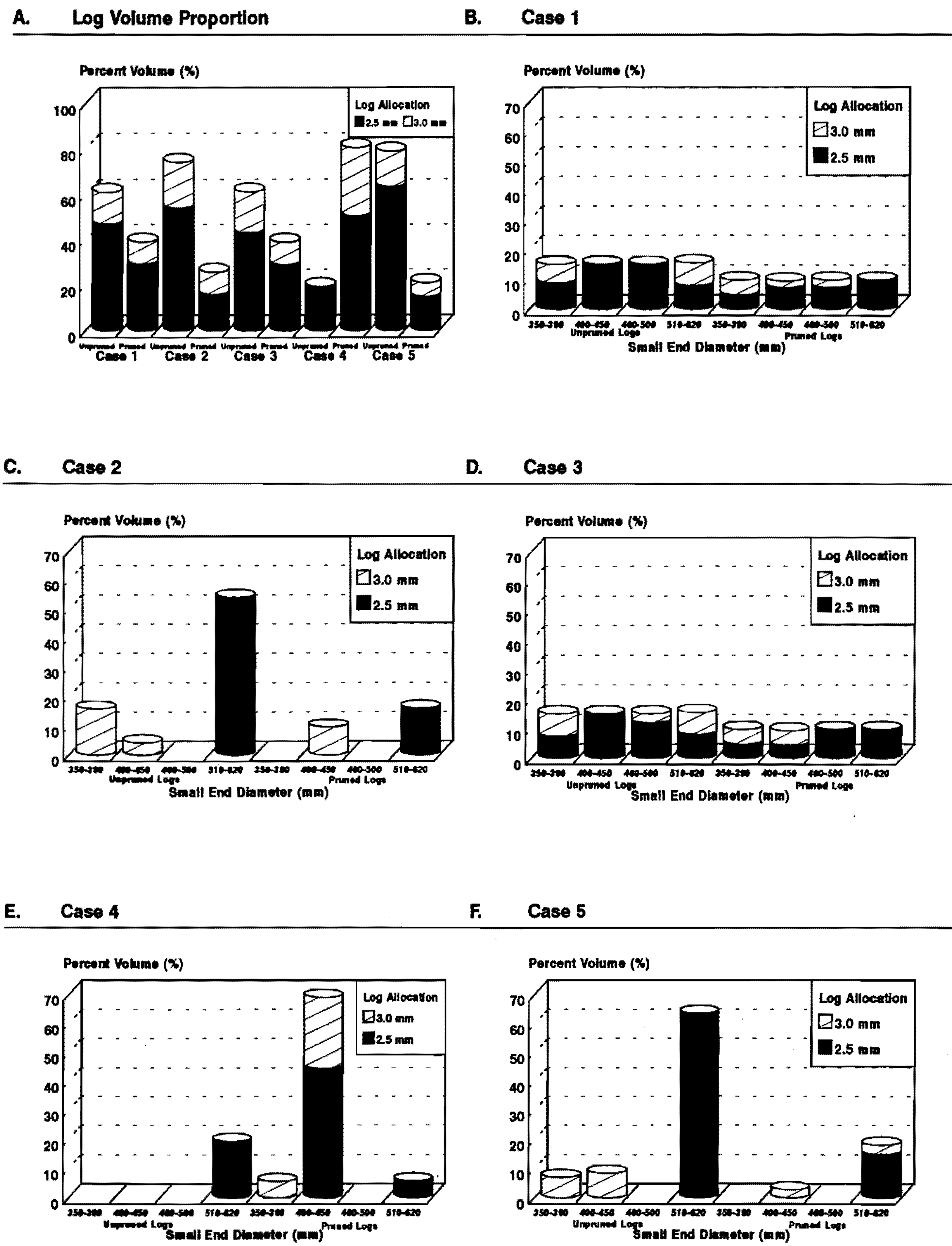


Figure 6-3. Log Allocation\Procurement by Log Type and SED Class of the 5 LOGPLY Case Studies.

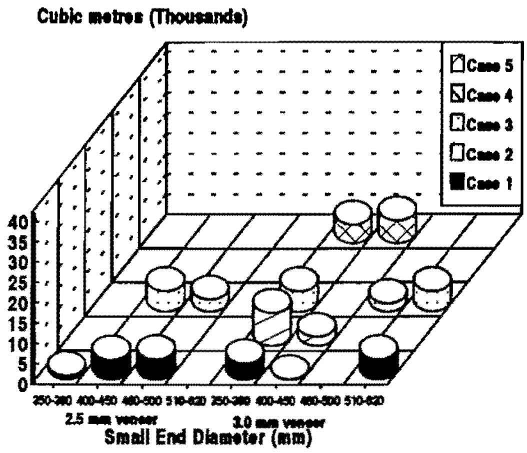
mm is predominantly selected SED class to procure. This is attributed to the utilisation of larger and higher yielding logs as discussed in Chapter 3. Bigger logs even at the same veneer recovery\conversion factor (VRR and VGRF) as smaller logs would tend to yield more veneers, with a tendency also to produce more high quality veneers.

The source of logs, aside from SED classes also played an important part in log allocation and procurement. The quality of logs, either pruned or unpruned, could be attributed to their source. The source of logs greatly affects the VRR and VGRF of logs as discussed in Chapter 3. Figure 6-4 shows the log allocation (Cases 1 and 3) or procurement (Cases 2, 4 and 5) according to log sources. Based on these figures, UP logs (Figure 6-4.B) are a more suitable source of unpruned logs than CB ones. Again, the 510 - 620 mm SED class in the case of UP and PP logs (Figure 6-4.B & C) is selected as the most preferred size for production needs. In RP logs, however, the 400 - 450 SED class is preferred, as shown in Figure 6-4.F. TPB and MP logs are not selected in optimally designed systems (Cases 2, 4 and 5) because of their lower VRR and VGRF in production of a set product mix. Thus, in pruned logs, RP and PP logs are preferred for production in these 3 cases. The allocation and selection of logs depend on their VRR and VGRF (see Chapter 3) and their prices. Thus, constant updating of the VRR and VGRF of logs is necessary to reduce adverse risk and uncertainty in both allocation and procurement of the most appropriate logs.

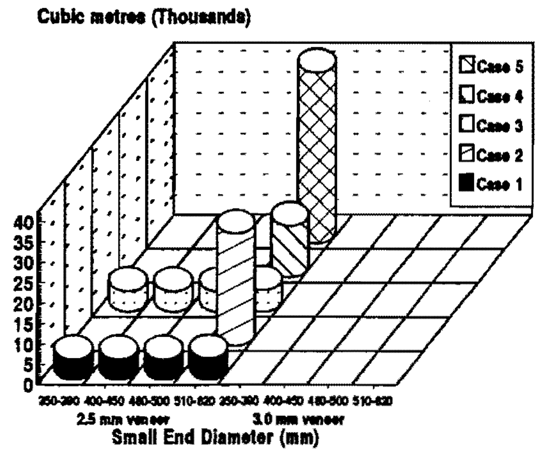
6.2.3 Log Ranking

Ranking or valuing individual logs according to their source, type and SED class range in terms of their plant production potential can be determined using the shadow prices in the model. The two most commonly recognised applications of

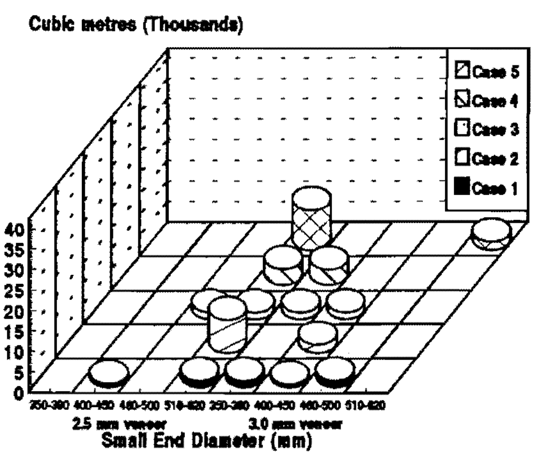
A. CB Logs (Unpruned)



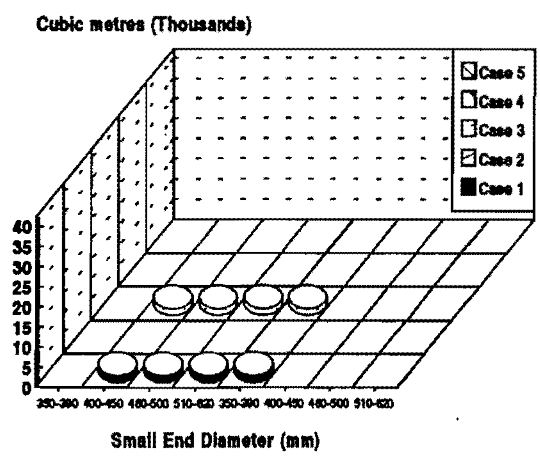
B. UP Logs (Unpruned)



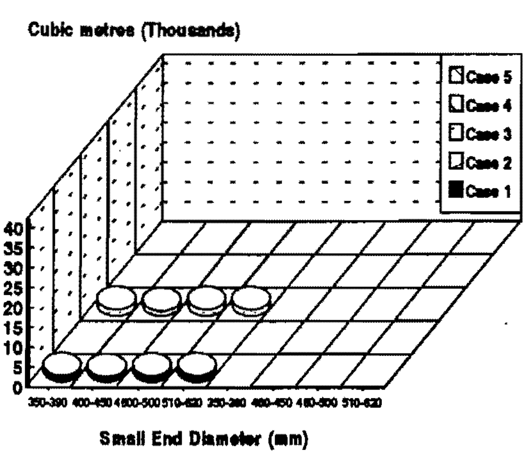
C. PP Logs (Pruned)



D. TPB Logs (Pruned)



E. MP Logs (Pruned)



F. RP Logs (Pruned)

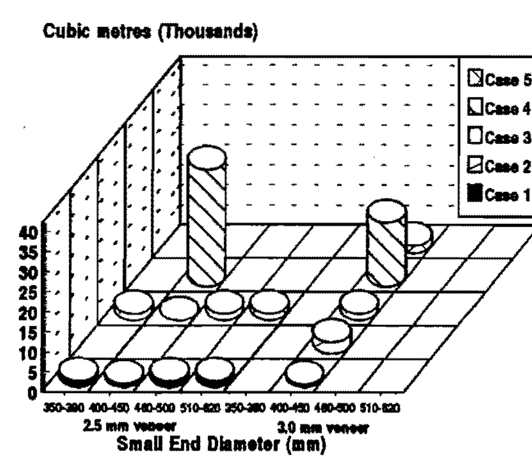


Figure 6-4. Log Allocation\Procurement by Log Source of the 5 LOGPLY Case Studies.

shadow pricing in a given system are: (i) in valuation problems, allocating the value of a profit to the portfolio of resources used to generate that profit; and (ii) in pricing problems, determining the maximum acquisition prices for additional units of these resources (Hessel and Zeleny, 1986). This section is most concerned with the pricing problem. In Table 6-1, the logs were ranked in accordance with their shadow prices

Table 6-1. Log shadow prices and their ranking in optimised given systems.

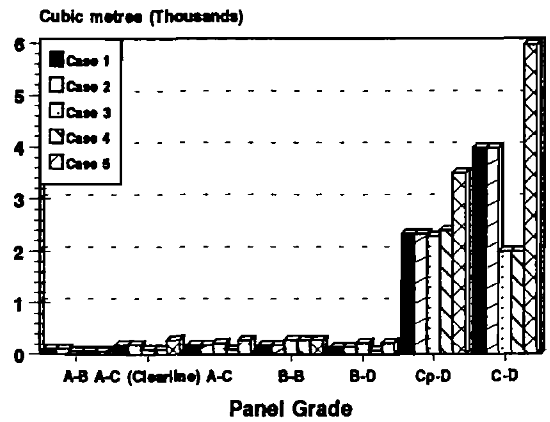
		Case 1		Case 3	
Log Code Name	SED Class range (mm)	Shadow Price	Ranking	Shadow Price	Ranking
CB	350 - 390	47.508	5	50.458	6
	400 - 450	43.934	7	43.862	8
	460 - 500	41.898	8	44.785	7
	510 - 620	35.424	9	33.146	12
UP	350 - 390	62.000	2	59.362	3
	400 - 450	49.461	4	50.499	5
	460 - 500	49.839	3	51.150	4
	510 - 620	99.468	1	104.000	1
PP	350 - 390	21.365	12	29.635	13
	400 - 450	26.892	10	35.352	10
	460 - 500	23.538	11	34.119	11
	510 - 620	46.250	6	61.140	2
TPB	350 - 390	11.976	19	18.512	17
	400 - 450	11.846	20	17.140	19
	460 - 500	3.183	22	5.899	22
	510 - 620	14.267	17	22.478	15
MP	350 - 390	1.973	23	3.4769	23
	400 - 450	0	24	0	24
	460 - 500	8.920	21	9.372	21
	510 - 620	15.121	15	17.883	18
RP	350 - 390	20.007	14	26.666	14
	400 - 450	26.347	13	37.339	9
	460 - 500	14.345	16	21.734	16
	510 - 620	13.252	18	13.946	20

or imputed costs for a given system (Cases 1 and 3). The shadow price of these logs is the added return that can be obtained if there were an additional cubic metre of the logs available for the respective case studies. It should be noted that these shadow prices are purely incremental, and could change significantly at different activity levels depending upon the constraint configuration. Thus, ranking the logs is determined through these values in formulating the priority list for buying logs. It is apparent that the value of the logs to the production depends on how the logs should be used, as shown in the different shadow prices for the same logs in Cases 1 and 3.

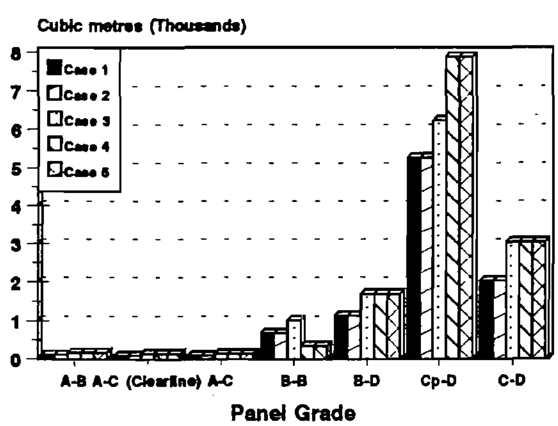
6.2.4 Product Mix

One purpose of presenting the case studies is to illustrate LOGPLY and eventually VENPLY as market-oriented LP models. The product mix and their markets as represented in the models by minimum panel order and the maximum sale-forecasted volume constraints are equally important components in profitability of veneer and plywood operations in addition to log allocation \ procurement activity. The prices for individual panel products and their quantity in the product mix determines the relative profitability of one to another. The product mixes and their layup options play an important role in the optimisation of the log resource, production environment and the market conditions. It is hard to pinpoint the main factor that ensures profitability of one product over another in a systems approach modelling like this. The interactions are complex, and have to be taken into account collectively in the model. Figure 6-5 clearly demonstrates, however, the relative profitability of one product over another as a result of the modelling. A product is profitable when the maximum sale-forecasted volume is produced, and it is unprofitable if the amount allocated is the minimum ordered volume. This is most clearly shown in cases which

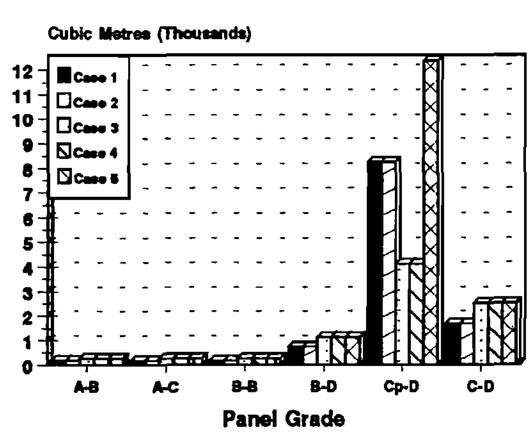
A. 7.5 mm Plywood (3 ply, 2.5mm veneer)



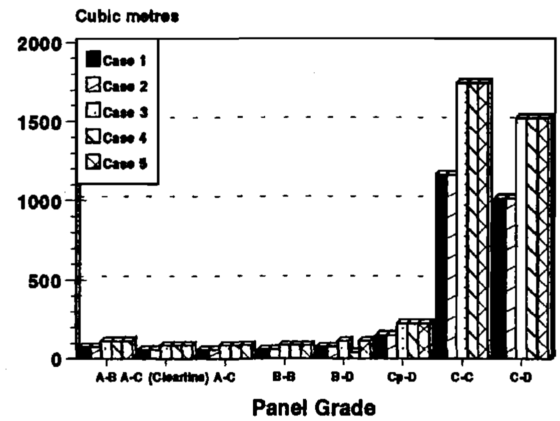
B. 12.5 mm Plywood (5 ply, 2.5mm veneer)



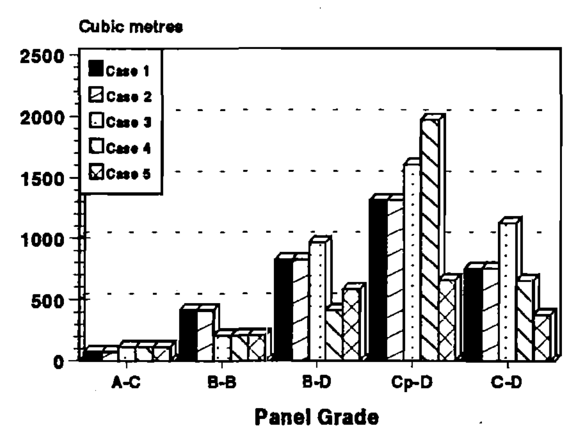
C. 17.5 mm Plywood (7 ply, 2.5mm veneer)



D. 9 mm Plywood (3 ply, 3.0 mm veneer)



E. 15 mm Plywood (5 ply, 3.0 mm veneer)



F. 21 mm Plywood (7 ply, 3.0 mm veneer)

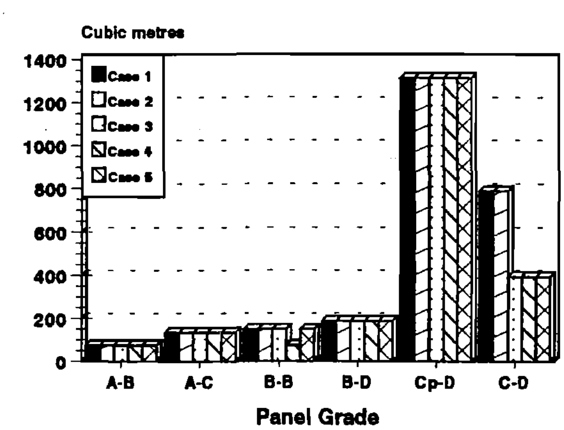


Figure 6-5. Product Mix Volume of the 5 LOGPLY Case Studies.

allow the model to take the upper limit of 50 percent above the basic production\market plan. The 7.5 mm panel products shown in Figure 6-5.A, for example, indicate that the A-B grade panel is a less profitable product than any of the other grades of 7.5 mm plywood or, for that matter, than any of the 12.5 mm and 17.5 mm which use the 2.5 mm veneer allocation. These results are evident in Cases 3, 4, and 5. The product mix of these cases is allowed to take an upper limit of 50 percent above the production/market plan if the product is profitable. The A-B grade panels are allocated to the lower limit; hence, the latter product is relatively unprofitable compared with the rest of the 7.5 mm panel grades in Cases 3, 4 and 5. It is also evident in Figures 6-5.A, B & C, that 7.5 mm products are unprofitable at current market price compared with the two other panels (12.5 mm and 17.5 mm) which use the same veneer, with the exception of B-B and Cp-D grades in those cases. Moreover, the profitability of the 15 mm panels (Figure 6-5.E) is more affected by market variations than are the 9 mm and 21 mm ones, which use 3.0 mm veneer allocations (Figure 6-5.D & F). Again, these results are true only in the case studies presented here. Thus, real time LP models such as LOGPLY and VENPLY allow comprehensive evaluation of the profitability of a product, because they can jointly reflect market demand, price and production condition for any chosen planning horizon. Market demands greatly affect log allocation or procurement just as much as does the allocation of veneer material to the different product mixes presented here. LOGPLY is needed in addition to VENPLY to identify fully the market potential of products by grade and thickness, because of the apparent importance in choosing the right log mix. Both models can cater for the needs of market-oriented manufacturing through using them in real time simulation or optimisation models for chosen, fixed values in the RHS's of the maximum and minimum sales of each product, then running them either by the *de novo* programming approach or in a traditional LP for allocating the log supply available for that period.

6.2.5 Veneer Allocation

The second stage of optimisation using LOGPLY is the allocation of different veneer grades to different panel products through choosing corresponding layup options. In Cases 1 and 2, for example, the product mix is identical, yet the veneer grade allocation to the different panel thicknesses and grade is entirely different one from the other, as shown in Figure 6-6. This can be attributed to the optimisation of veneers to different layup options in different thicknesses and grade. In 7.5 mm panels, the volume of veneer grade combinations in the two case studies are almost equal, except for Cp and HCp veneers(Figure 6-6.A & C). However, the rest of the panels (12.5 mm and 17.5 mm) which use and compete for 2.5 mm veneers are entirely different. This trend is also shown in 3.0 mm veneer allocation for 9.0 mm, 15.0 mm and 21.0 mm panels (Figure 6-6.B & D). The difference in the two veneer allocations can be attributed to the optimisation of veneer produced from the optimised log allocation.

Another point to stress is that, in LOGPLY, the value of logs is what is primarily optimised rather than the value of veneers to produce the product mix, as is evident in the veneer downgrading. This is probably one weakness of LOGPLY, especially for extended planning time horizons where the planning and scheduling of product mix are not confined to the logs available at any one given time. In other words, planning is not done in a holistic way from logs to plywood but only from veneers to plywood. The type of planning most commonly practised in veneer and plywood operations is wasteful as manifested in the huge amounts of

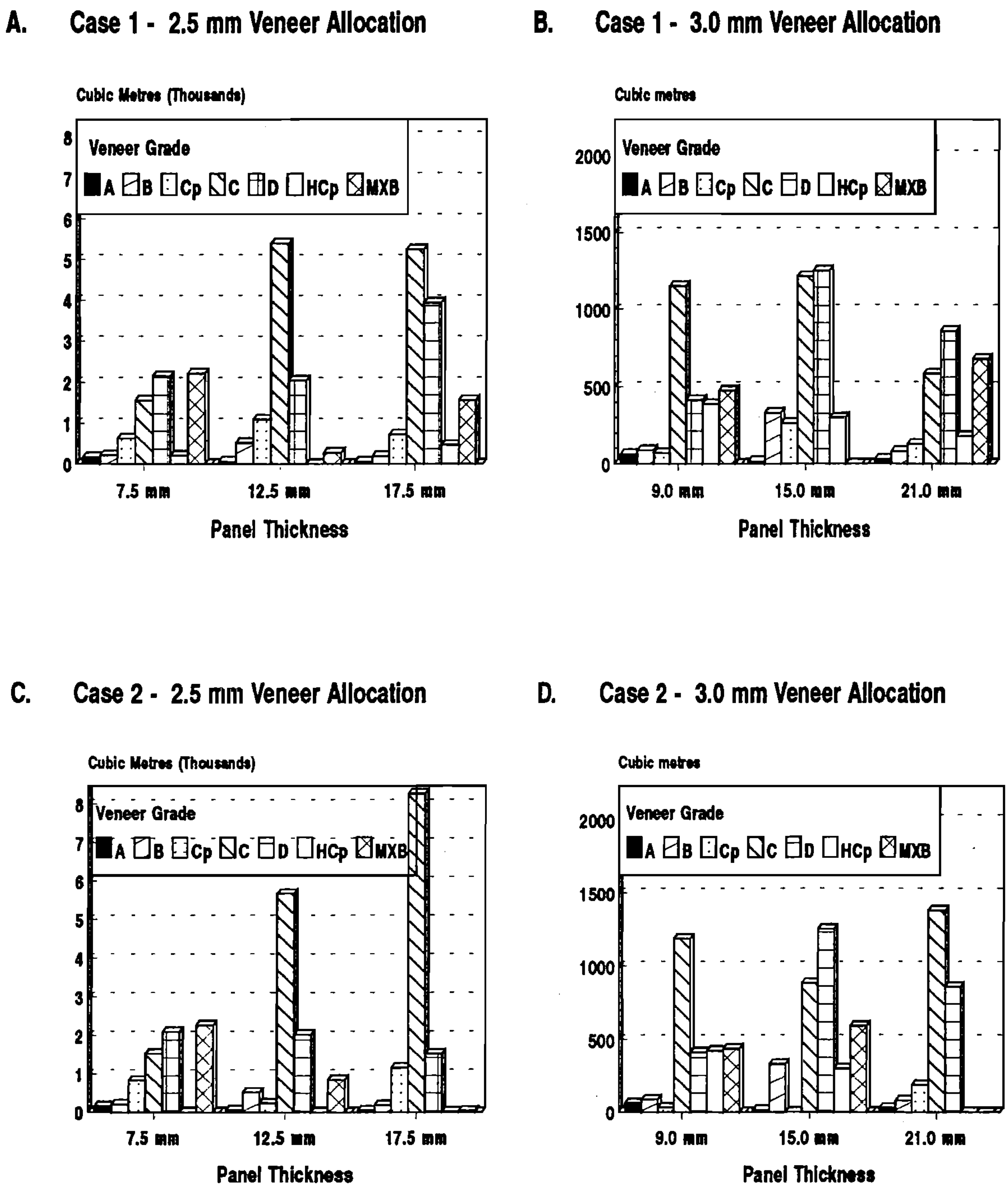


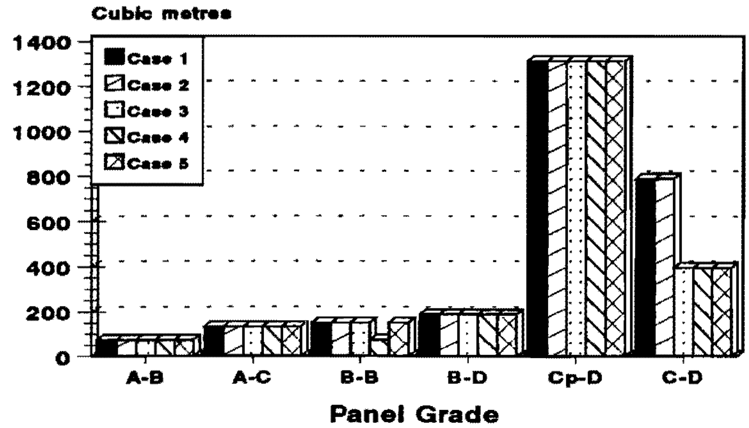
Figure 6-6. Veneer Grade Allocation by Veneer and Panel Thickness of LOGPLY Cases 1 and 2.

veneer inventory that are usually held. This weakness can be overcome through using VENPLY, which will be discussed later in 6.3.

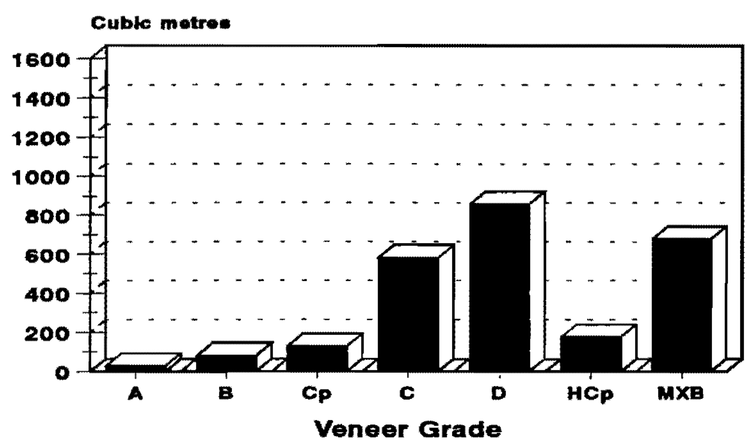
6.2.6 Product Layup Options

LOGPLY determines the layup options for the products in relation to available log resources, production capacities and market demands without the need for intellectual guesswork. To demonstrate this capability, the veneer allocation for a panel grade of a certain panel thickness e.g. 21 mm panel (Figure 6-7.A) can be analysed and interpreted. To simplify the discussion, results of Cases 1 and 2, specifically the veneer allocation of 21 mm panel are examined. The quantities of different veneer grades from the two cases bear little or no relation to one another, even though the panel grade volumes are equal (Figure 6-7). The reason for this is that the model has chosen a different layup option for each panel grade to take into account the varying conditions as shown in Figure 6-8. In Figure 6-8 A, B, C & D, Case 1 used the first of the 4 options in different panel grades, while Case 2 used the fourth option. In Figure 6-8.E, Case 1 split up how the Cp-D should be manufactured by choosing the first and fifth options among the 8 options, while Case 2 used only the fourth option. In C-D grade (Figure 6-8.F), Cases 1 and 2 used the same layup option to produce the product. Thus, choice of layup options provides a main ingredient for profitable plywood manufacturing. General observations are that panel layup options in a plywood plant are almost always violated in favour of concern for productivity. Most veneer and plywood managers allow productivity to be preferred over economic efficiency and wise utilisation of raw materials when measuring the efficiency of an operation. This is evident in that a large quantity of veneer inventory, especially lower grades, is usually found in a plant.

A. 21 mm Plywood (7 ply, 3.0 mm veneer)



B. Case 1 - Veneer Allocation 3.0 mm (21 mm Plywood)



C. Case 2 - Veneer Allocation 3.0 mm (21 mm Plywood)

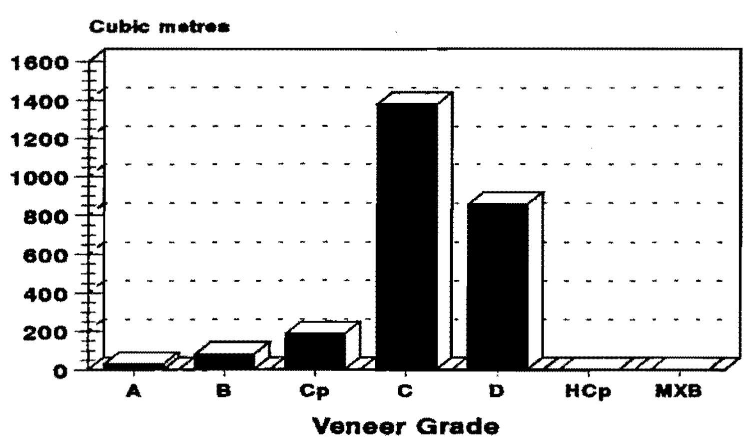
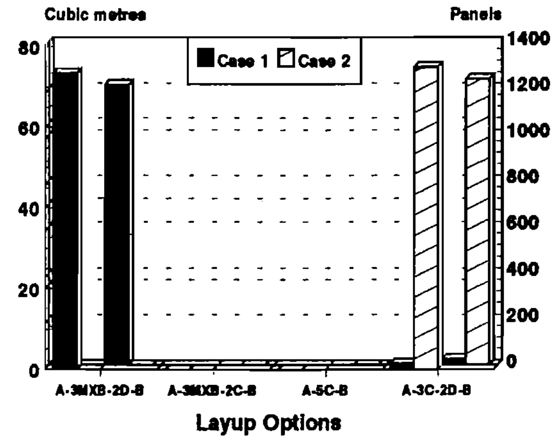
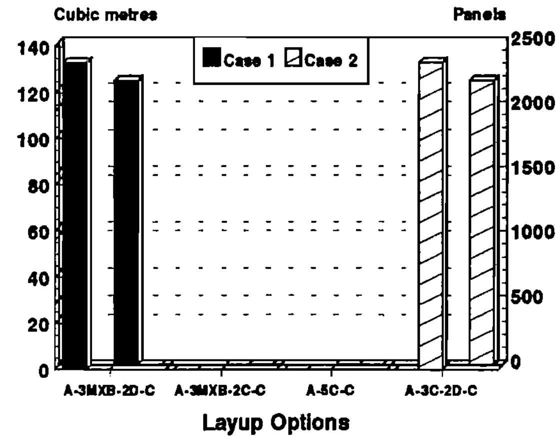


Figure 6-7. Panel Volume and Veneer Grade Allocation of 21 mm Panel in LOGPLY Cases 1 and 2.

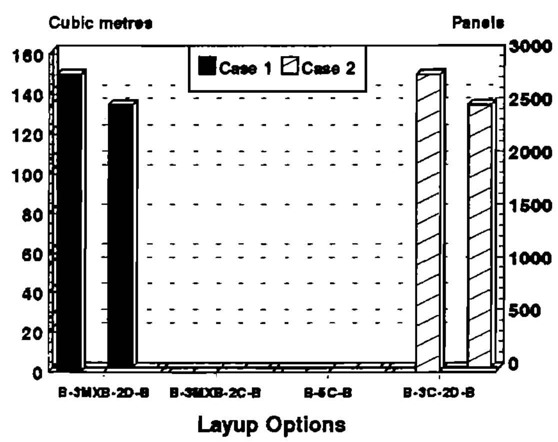
A. A-B Grade (21 mm Plywood)



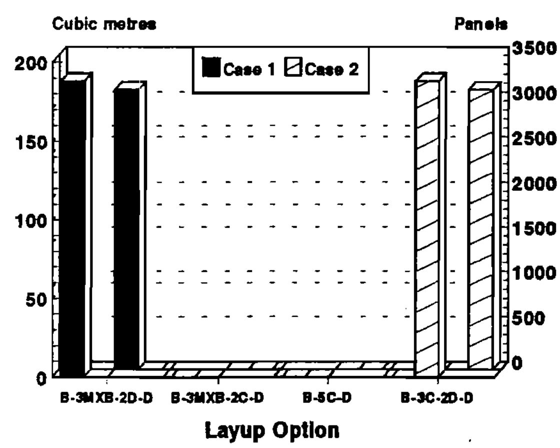
B. A-C Grade (21 mm Plywood)



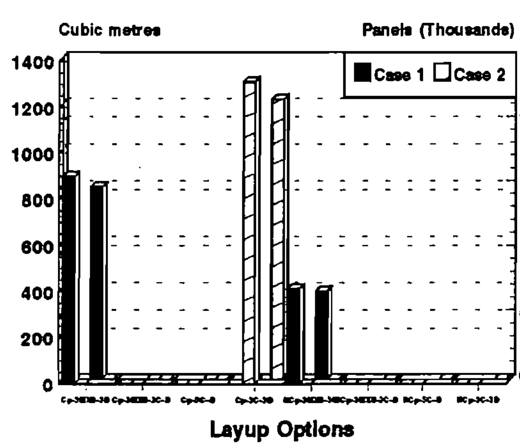
C. B-B Grade (21 mm Plywood)



D. B-D Grade (21 mm Plywood)



E. Cp-D Grade (21 mm Plywood)



F. C-D Grade (21 mm Plywood)

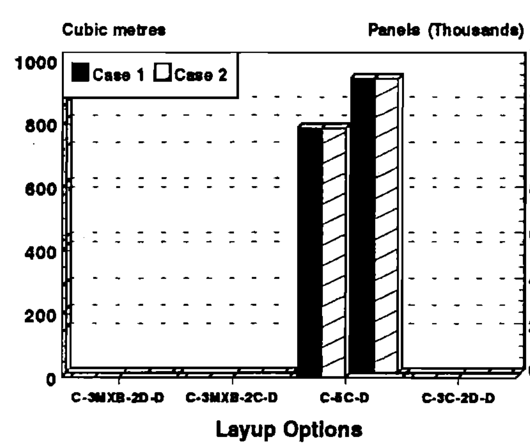
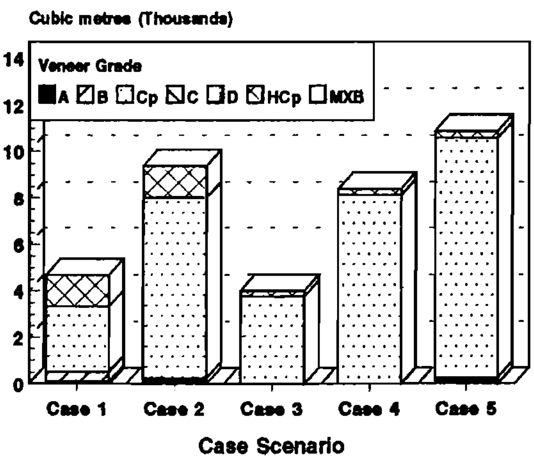


Figure 6-8. Panel Layup Options Results of 21 mm Panel in LOGPLY Cases 1 and 2.

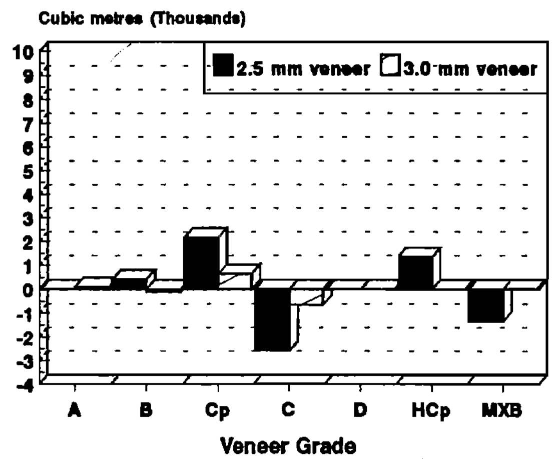
6.2.7 Veneer Downgrading

One question production managers very frequently ask is whether or not it is profitable to downgrade veneers. The case study results suggest that it is profitable to downgrade them (see Figure 6-9). The reason for veneer grading is optimisation of the product outturn value from the chosen logs in LOGPLY. In Figure 6-9.A, all of the cases resulted in some downgrading of veneer grades in order to produce the desired product mixes. Even though a penalty were to be imposed for downgrading veneers (in the 5 cases, there was none, however), these veneers would most likely be downgraded anyway. The value of logs is what is primarily optimised in LOGPLY rather than the value of veneers, as explained earlier. In the five case studies, some Cp veneer is always downgraded (Figure 6-9.B, C, D, E & F). In Cases 2, 4 and 5, Cp veneer is downgraded to C and D veneers. Implicitly, then, Cp veneers are valued as either C or D grade, as the case maybe. It is wise, therefore to implement a new clipping strategy that would not differentiate Cp, C or D to manufacture these product mixes. The new clipping strategy would likely increase the VRR of the logs, especially unpruned ones. Unpruned logs, it should be remembered, are expected to produce only Cp, C, and D veneers. All unpruned logs, however, should not necessarily have this new clipping regime, since the product mix requires Cp-D grade to be produced. The veneer downgrading problem can be alleviated by using VENPLY as a second optimiser, an aspect to be discussed later in 6.3. Nevertheless, LOGPLY demonstrated that downgrading could be a profitable activity, provided that logs are to be optimised in the planning horizon. This implies that a real time LOGPLY model is necessary to determine how veneer downgrading should be allowed to proceed in each planning period, especially when planning is done from logs to finished products.

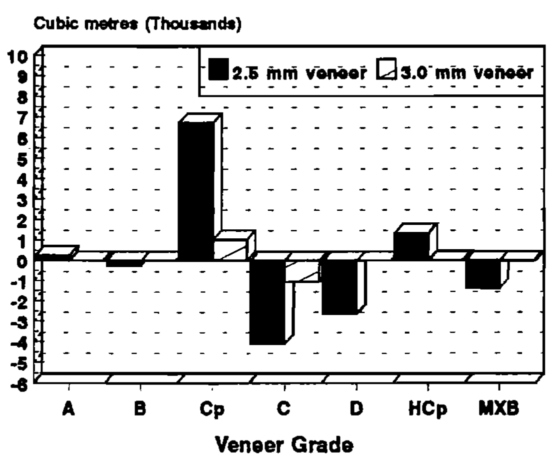
A. Veneer Downgrading



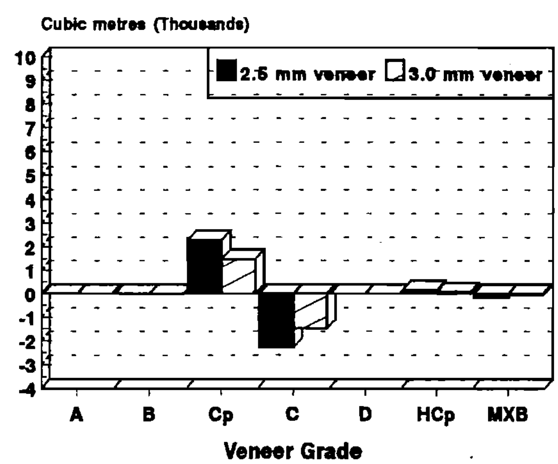
B. Case 1 - Veneer Downgrading and Usage



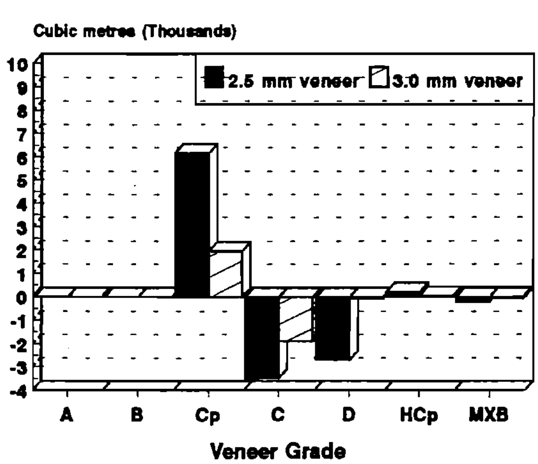
C. Case 2 - Veneer Downgrading and Usage



D. Case 3 - Veneer Downgrading and Usage



E. Case 4 - Veneer Downgrading and Usage



F. Case 5 - Veneer Downgrading and Usage

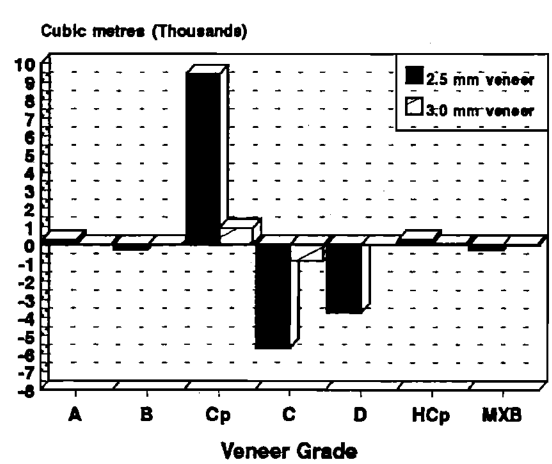


Figure 6-9. Volume of Veneer Downdgraded in the 5 LOGPLY Case Studies.

6.2.8 Machine Time Allocation

This section demonstrates the capabilities of LOGPLY as a manufacturing LP model. The production capacities of the plant through the machine centres in veneer and plywood sections are closely examined in relation to the optimised log allocation and product mix. Machine time allocation is very important for scheduling and analyzing the bottlenecks of the operation. This can be done through simulating a desired production schedule to be implemented in each of the 5 case studies. Although possible bottlenecks can be identified using the results from the time and motion studies reported the Chapter 3, LOGPLY can further identify and quantify the cost of a bottleneck in terms of the whole system rather than by its constituent parts. Although the available machine times for all machine centres in the case studies were simulated in the model by running first the model with the product mix of Case 1 and available logs to determine the time required to manufacture them, the principle of quantifying bottlenecks could still be followed. In Case 1, the bottleneck is the glue spreader. The shadow price is \$2.4 x 10^{-10} per minute, an insignificant figure, but this machine is critical to the production for this case, an additional minute available to the production being able to increase the gross revenue by \$ 2.4 x 10^{-10}. In Case 2, the glue spreader is again a limitation \$5.78 x 10^{-10} per minute, which verifies the bottleneck. In Case 3, the stringer and sander, \$1.5458 per minute and \$15.25 per minute respectively, are the limiting factors. In Case 4, the dryer and sander, \$24.742 per minute and \$17.0 per minute respectively, hold up the system. In Case 5, no machine time restriction exists for the machine centres, hence there are no bottlenecks.

This analysis sheds insights into the arguments among production managers of different plants about whether the dryer or spreader is the bottleneck in production.

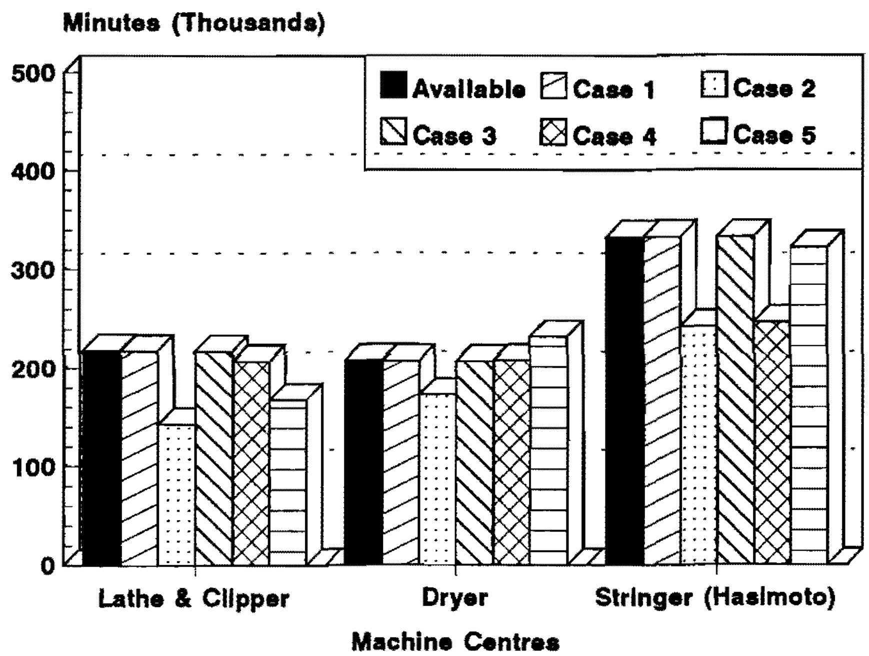
It is clearly demonstrated in these case studies that bottlenecks are dynamic features that depend on plant \machine layout, machine rates, production schedule (e.g. no. of shifts, no. of working days), and product mix to be produced. Thus, overall systems models such as LOGPLY and VENPLY provide a sensitive tool for identifying and quantifying possible bottlenecks.

The different machine time allocations by section and machine centre are shown in Figure 6-10. In Figure 6-10.A, machine time allocations for the veneer section are sufficient in most cases, except for the dryer in Case 5. In the plywood section (Figure 6-10.B), the machine times are all used up. Detailed explanations of such matters are dealt with in the next subsection.

I. Lathe and Clipper Time Allocation

Figure 6-11 shows the lathe and clipper time allocation for different case studies, veneer thickness and SED class, together with corresponding log volumes being processed. In Figure 6-11.A, the optimally designed systems (Cases 2, 4 and 5) did not use up all the available lathe and clipper machine time, because the model chose the high yielding logs with lesser time to process them. Thus, a lower volume of logs is being processed, which produces a good veneer combination that satisfies the veneer requirement for the product mix. Figure 6-11.C, E & F show time allocations for the optimally designed systems. At this point, it is also important to emphasize the relevance of processing bigger logs, as shown in Figure 6-11.B & D. Lathe and clipper processing time would be less in bigger logs for the same volume as well as yielding more veneers than can be recovered or converted from smaller logs.

A. Machine Time - Veneer Section



B. Machine Time - Plywood Section

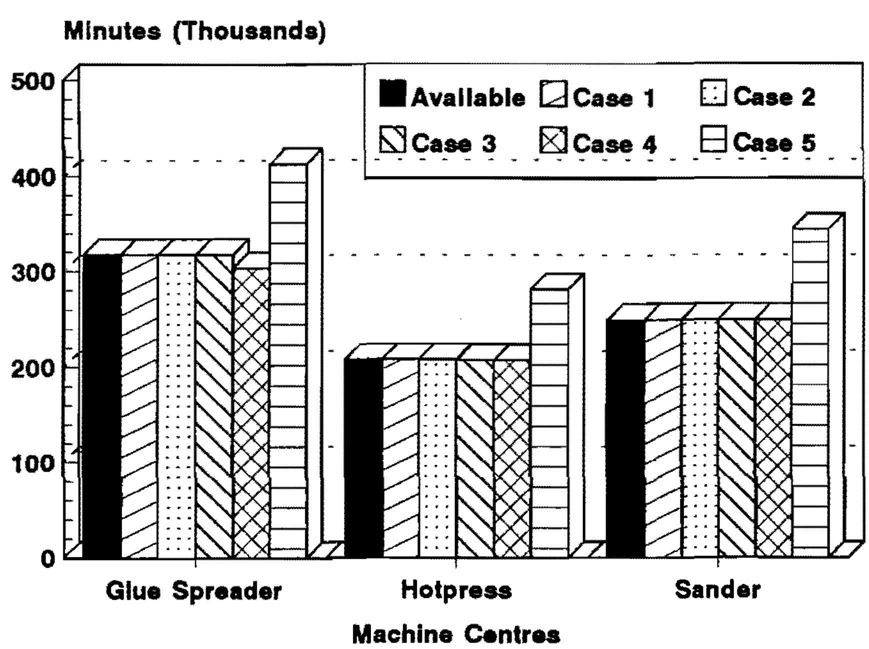


Figure 6-10. Machine Time Allocation by Production Section and Machine Centre in the 5 LOGPLY Case Studies.

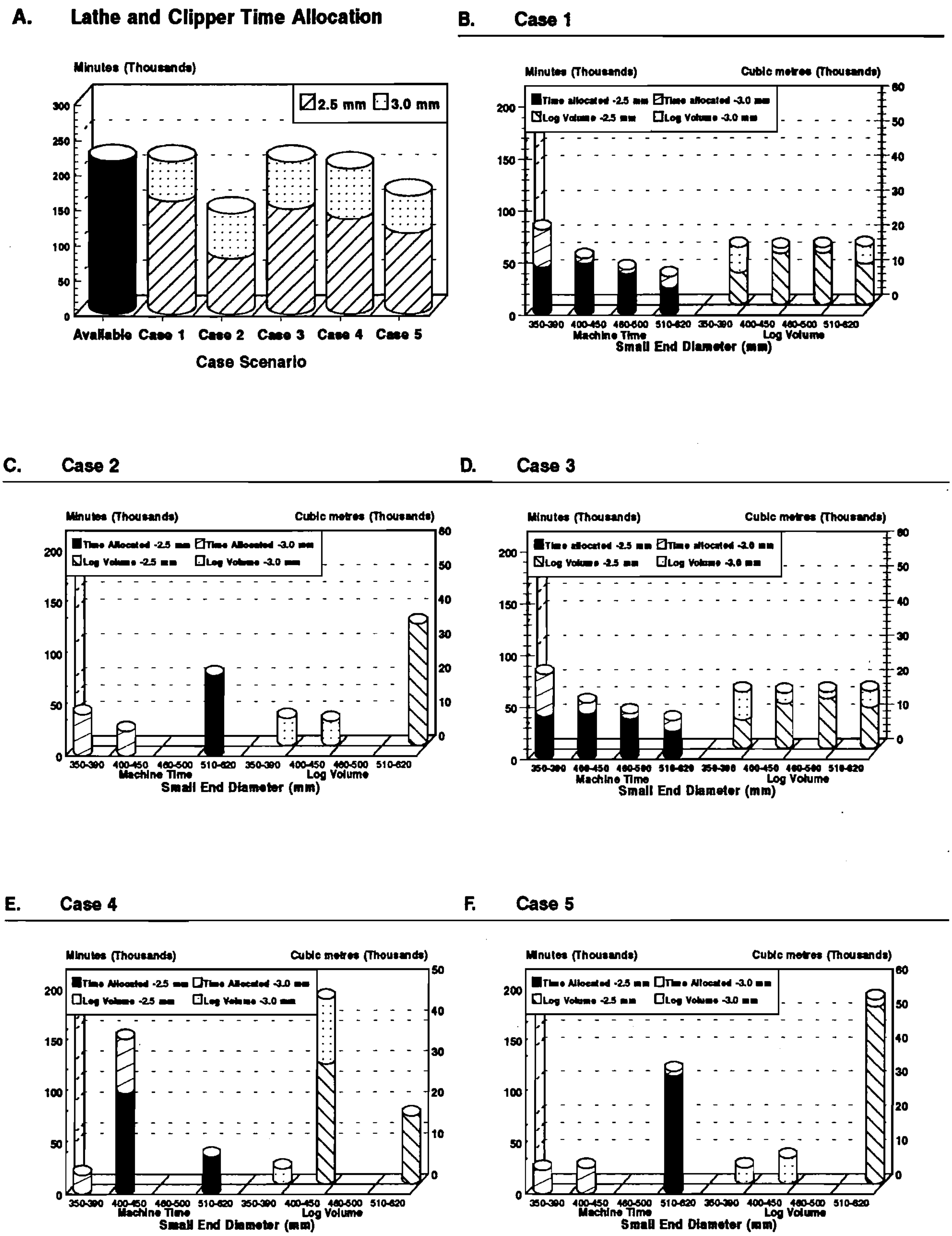


Figure 6-11. Lathe and Clipper Time Allocation in the 5 LOGPLY Case Studies.

II. Dryer Time Allocation

The dryer is considered here to be part of a continuous process as mentioned in 3.3.4. Thus, drying time could be analysed according to the SED classes of the logs, as shown in Figure 6-12.B to F. The veneer volume recovered from SED log classes is attributed to the dryer time allocation as shown in Figures 6-12.B & D. The SED log class is directly proportional to the dryer time allocation due to more veneers being fed to the dryer from larger logs as opposed to smaller logs, when the same volume of logs is processed prior to dry clipping. In the lathe, more veneer round-ups, which eventually turn to hog fuel, and log cores are generated from smaller than larger logs. The difference in the volumes between logs and byproducts is the amount of veneer fed to the dryer in a continuous process before dry clipping - that is what determines the usable veneers. Figures 6-12.B & D show clearly the dryer time allocated and veneer recovered from the different SED log classes for the same volume of logs processed in these cases. Thus, more dryer time is needed to dry veneers from bigger logs. The importance of bigger logs for production as well as in optimally designed systems can be further illustrated and clarified through Case 2 (Figure 6-12.A), where it can be seen that the dryer time needed to dry the required veneers for the product mix is less than the available dryer time or the dryer time allocation for Case 1, although Cases 1 and 2 produce an identical product mix in terms of volume and grade.

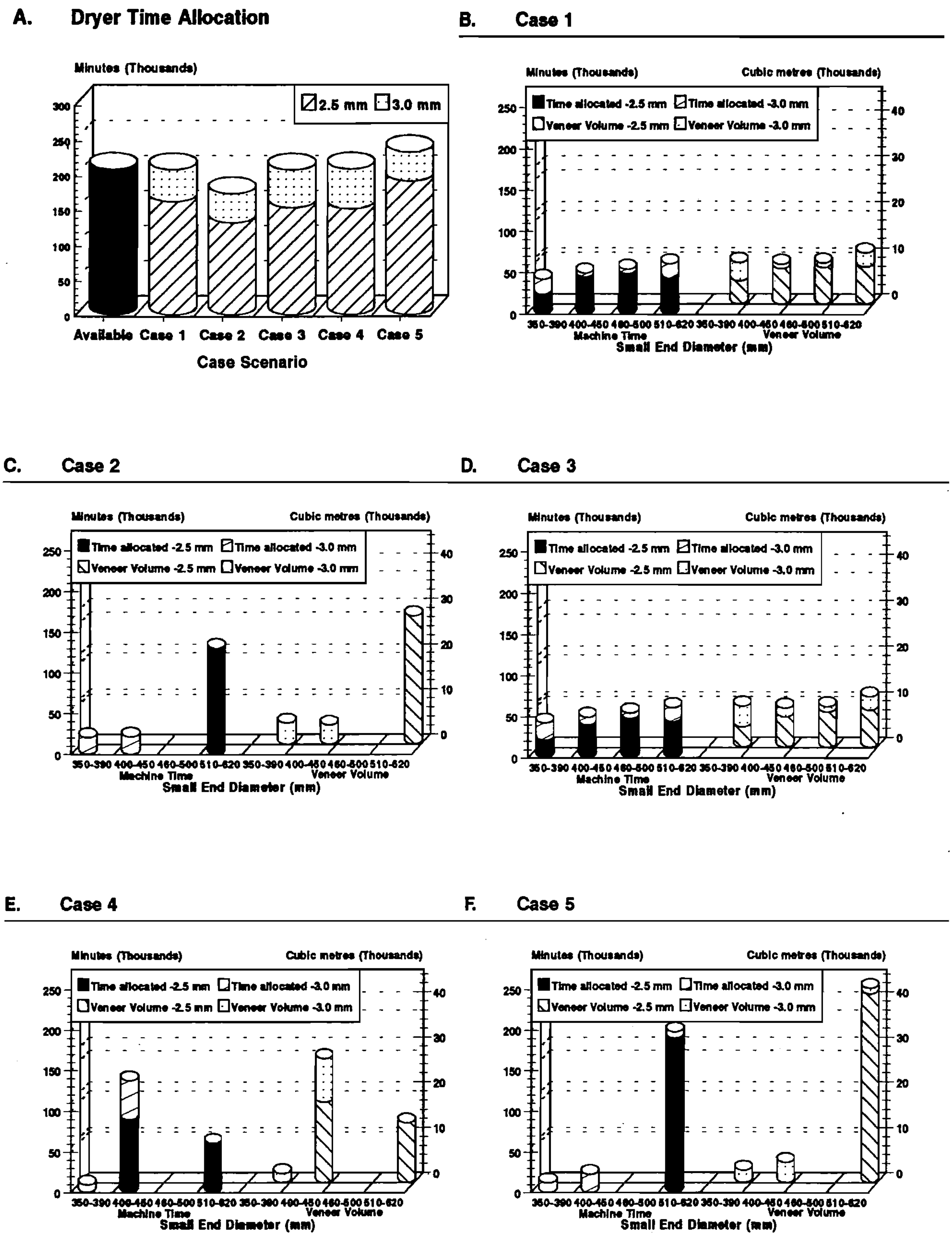


Figure 6-12. Dryer Time Allocation in the 5 LOGPLY Case Studies.

III. Stringer (Hasimoto) Time Allocation

One important aspect to note from these case studies is that stringer time allocation in the optimally designed systems, Cases 2, 4 and 5, shows that the logs selected to produce the product mix result in fewer multi's. Thus, the stringer machine availability is less than the time available (Figure 6-13.A). For 3.0 mm veneers, less stringer time is needed to produce the same volume of stringed corestock than in 2.5 mm veneers, as shown in Figures 6-13. B to F. This can be ascribed to the difference of veneer thickness.

IV. Glue Spreader Time Allocation

Like the dryer, the glue spreader is usually suspected to be a bottleneck or at least a factor constraining production. In the case studies presented here, the glue spreader was found to be a constraining factor in Cases 1 and 2, as mentioned earlier. In all cases, the full sheet corestock is preferred for use over the MXB corestock (Figure 6-14.A). This can be attributed to easy handling and feeding that can result in a faster rate of production using full sheet corestock than MXB corestock. Automatic downgrading of full sheet veneers by cutting them and making them into corestock for the sake of speeding up production is not to be recommended. Nevertheless, in most cases reported here, Cp downgrading is part of the total approach needed to optimise the use of the log resource, employing efficient production and meeting market demands. This is also the reason for presenting the detailed machine time allocation for different centres in all cases. In Figure 6-14.B to F, glue spreader time allocations for the individual case studies are shown by panel thickness, corestock thickness and corestock

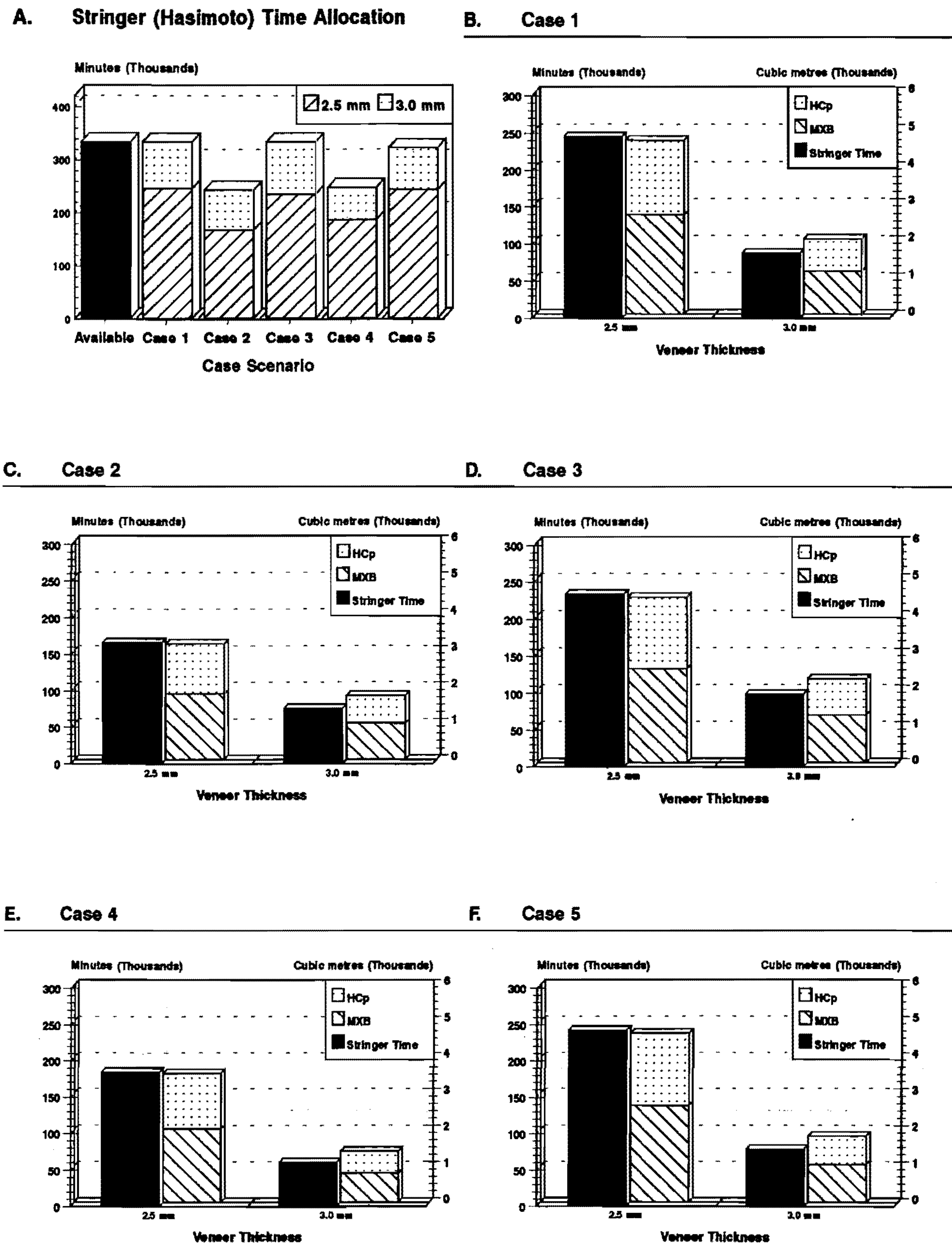


Figure 6-13. Stringer (Hasimoto) Time Allocation in the 5 LOGPLY Case Studies.

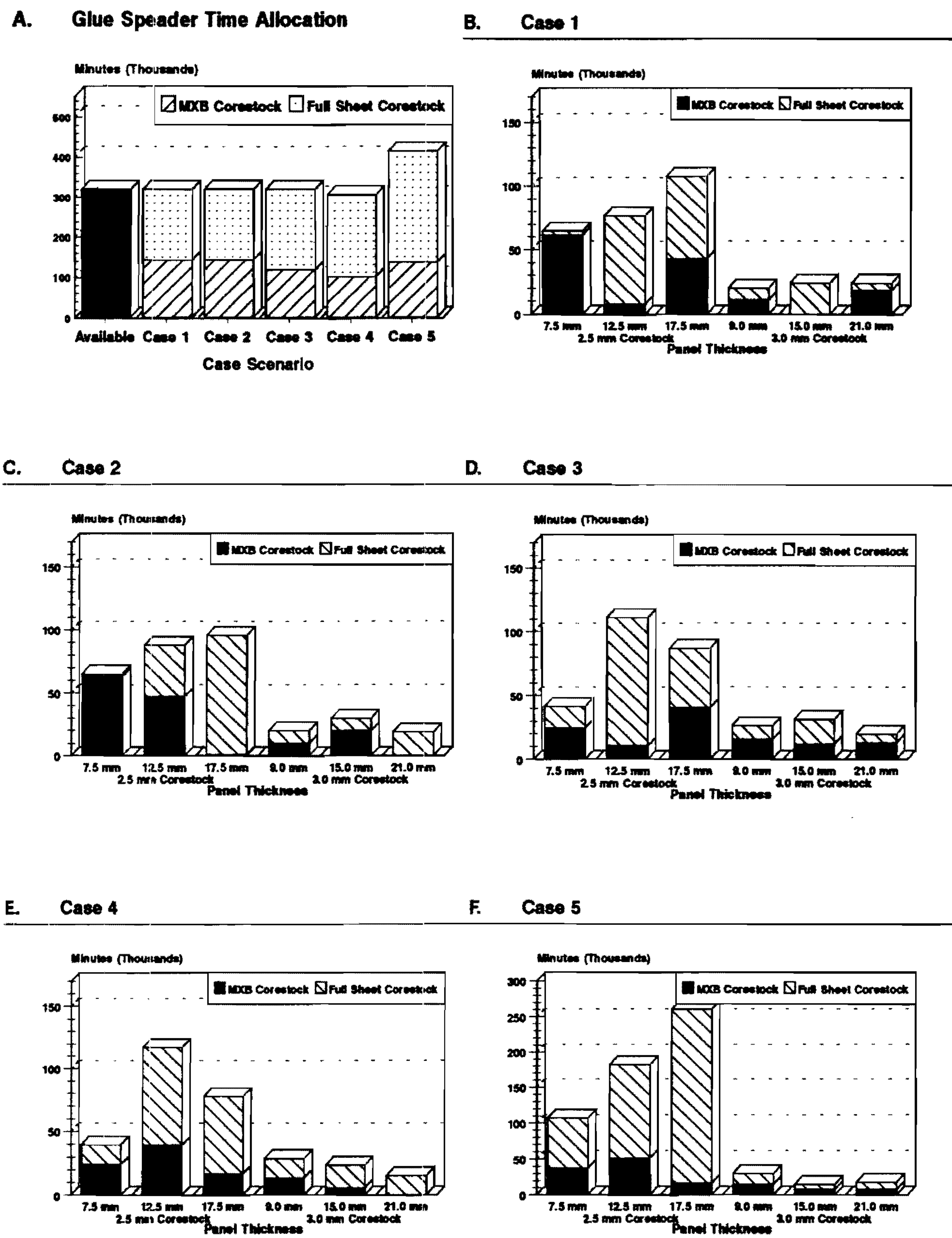


Figure 6-14. Glue Spreader Time Allocation in the 5 LOGPLY Case Studies.

type. In all cases, MXB corestock is used more in 3 ply construction (7.5 mm and 9.0 mm panels) than for other panels, since their construction easily builds-up the volume of panels at the same spreader rate (see Appendix C.IV for the glue spreader rate). Thus, stringed corestocks could generally be formed in 3 ply construction or in panels with lower ply numbers, to improve productivity.

V. Hotpress Time Allocation

In the cases studied and presented here, the hotpress did not appear once as production bottleneck. The hotpress productivity, however, is always affected by the rate of throughput on the glue spreader. Thus, proper coordination of the two machines is needed to avoid dry-up, which is pre-curing of glue, as mentioned in 3.3.7. But the hotpress operation can always be extended to accommodate the last batch of assembled panels. In Figure 6-15, the hotpress time allocation for each case, the panel thicknesses and grades show just how helpful LOGPLY and VENPLY can be in the proper allocation of machine time. It is interesting to note that thinner panels require more time to be pressed for the same volume produced than thicker panels, as shown in Figure 6-15. B to F. Thus, it is wrong (uneconomic) to price panels of the same grade but with different thicknesses, as is sometimes done in practice.

VI. Sander Time Allocation

The sander time allocation demonstrates also the relevance of panel thickness on production and product pricing. The sander time allocation

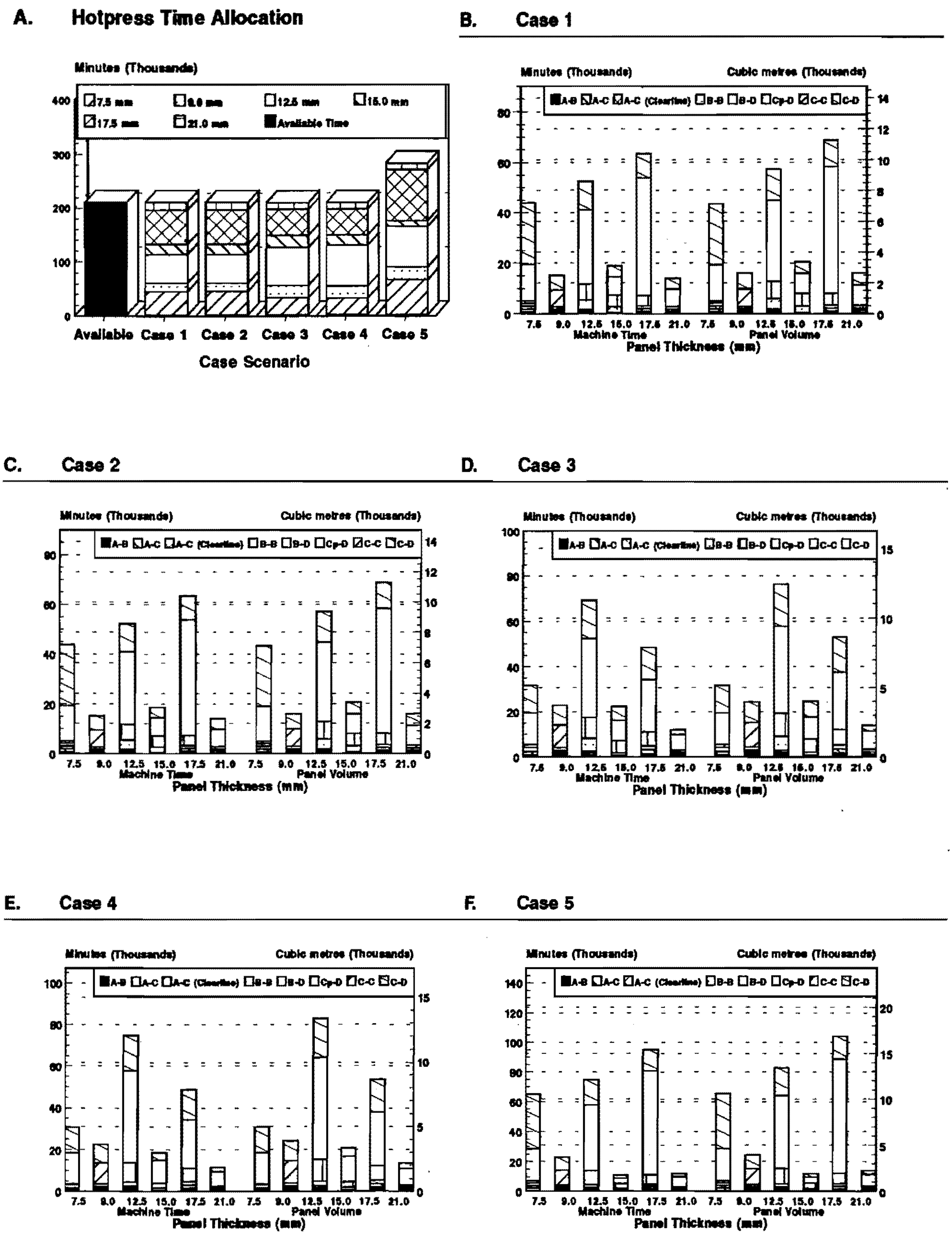


Figure 6-15. Hotpress Time Allocation in the 5 LOGPLY Case Studies.

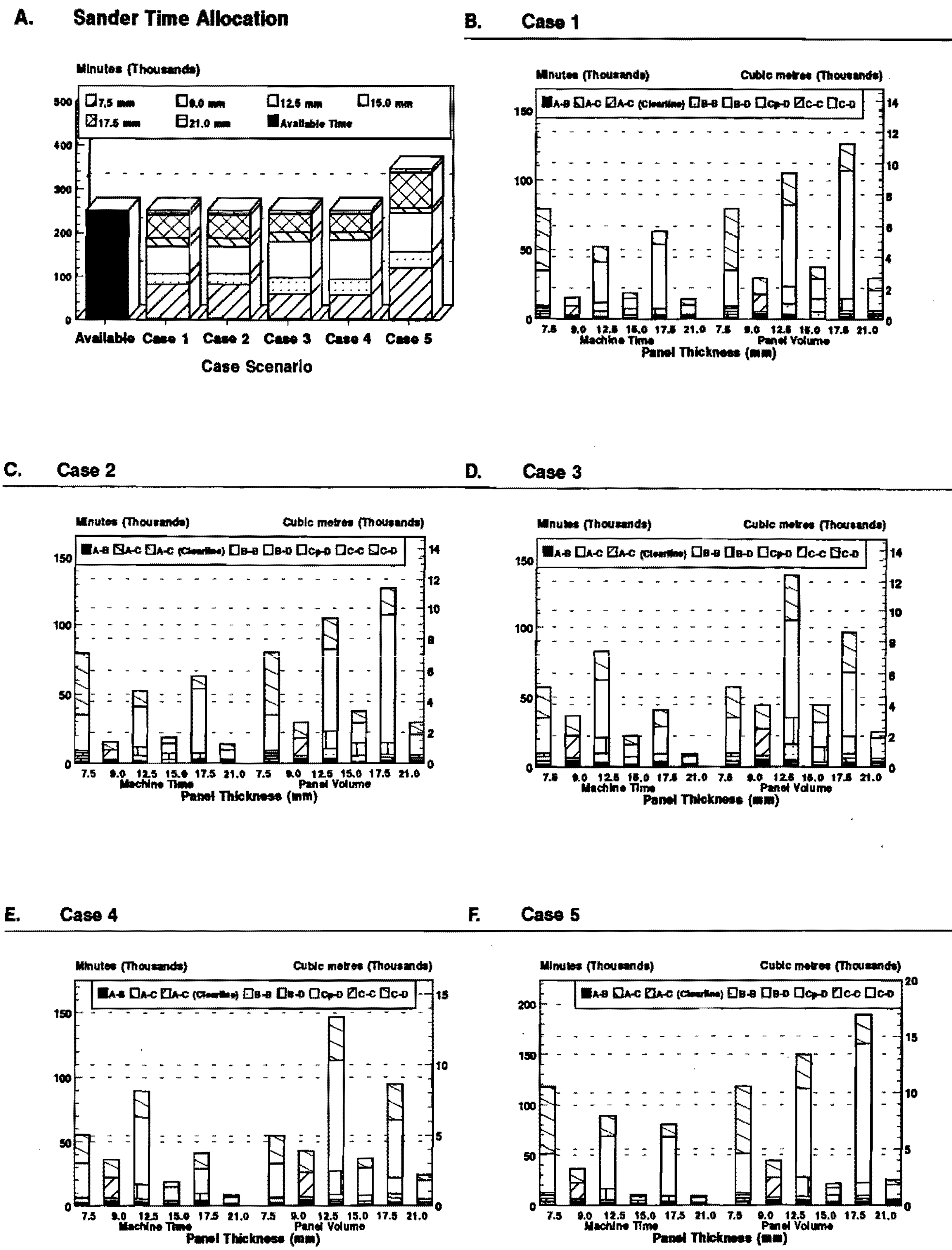


Figure 6-16. Sander Time Allocation in the 5 LOGPLY Case Studies.

depends on the surface area of the panels. Thus, for the same volume of panels, thinner ones require more time than thicker panels or in other words, thicker panels require less sanding than thinner panels, as shown in Figure 6-16. B to F. The sander time allocations by cases and panels thickness are shown in Figure 6-16.A to show the utility of LOGPLY and VENPLY for production scheduling in addition to other optimising capabilities.

6.3 The VENPLY Case Studies

The VENPLY case studies demonstrate the capability of the model as: (i) a secondary optimiser and one that is complementary to LOGPLY; and (ii) another system to address short term needs of optimising the veneer inventory. VENPLY shows that the apparent weakness of LOGPLY can be remedied by eliminating the veneer downgrading. The model was built with the same database as for LOGPLY (see detailed description in Chapter 5) and identical product mix and layup options. Lathe, clipper and dryer machine centres are discarded as these machine centres are not involved in processing veneers to plywood. The four VENPLY case studies further elaborate how these two models can work in tandem to address the needs of decision-making in veneer and plywood operations as a whole.

6.3.1 Case 6: An Optimised Given System

Case 6 is adapted from the LOGPLY Case 1 study. The veneer allocation to the product mix in Case 1 is taken and priced according to the new procurement prices for the different veneer grades as shown in Table 6-2. A corresponding penalty cost of $ 25 per cubic metre is imposed if a selected veneer is downgraded from one grade to other. These new procurement prices and penalty costs are used in the succeeding VENPLY case studies. The procurement and penalty costs comprise the total veneer cost for Case 6. The gross revenue of panels in Case 1 is also the gross revenue for Case 6. The revenues from the byproducts (hog fuel and log cores) were discarded for this case study and the rest of the case studies to simplify the analysis.

Table 6-2. Assumed procurement cost of different veneer grades.

Veneer Thickness	Veneer Grade	Price ($\$/m^3$)
2.5 mm	A	600
	B	550
	Cp	500
	C	450
	D	380
	Raw MXB	200
3.0 mm	A	600
	B	550
	Cp	500
	C	450
	D	380
	Raw MXB	200

6.3.2 Case 7: Designing an Optimal System with Machine Constraints

This example demonstrates once again the *de novo* programming approach to designing an optimal system; it designs the veneer input availability part of the model. The optimal veneer allocation is determined using the veneer procurement and penalty costs in Case 6. The product mix to be produced for the market is the same as in Cases 6 or 1. The total panel volume is still 36 423 cubic metres. The production capacities or machine constraints (RHS) for the: stringer; glue spreader; hotpress and sander are all the same as in Case 1.

6.3.3 Case 8: Designing an Optimal System without Machine Constraints

This case study is basically almost the same as Case 7. The only difference is in the production capabilities of the machine centres; instead of placing the production constraints for the case study, the model is free of any machine rate limitations and is able to select whatever materials are suitable for the production of the product mix that optimises its revenue. This example, therefore, simulates the importance of having unlimited machine time or at least faster machines in production. In other words, the production capacities would in no way affect production of the intended products. The total panel volume is equal to 36 423 cubic metres.

6.3.4 Case 9: Designing an Optimal System with Market Variation

This case is very similar to Case 8, through a flexible veneer requirement for the product mix. The production constraint aspect is again dropped to show how the model improves its revenue without production constraints. Furthermore, the importance of the market was taken into consideration with the assumption that the product mix market demand is allowed to vary as high as 50 % above the production\market plan for the maximum volume, except for the 21.0 mm panels which are set at the production\market plan. The minimum volume of individual panel grade is 50 % less than in the production\market plan. The total panel volume is still equal to 36 423 cubic metres.

6.4 Results and Discussion of VENPLY Case Studies

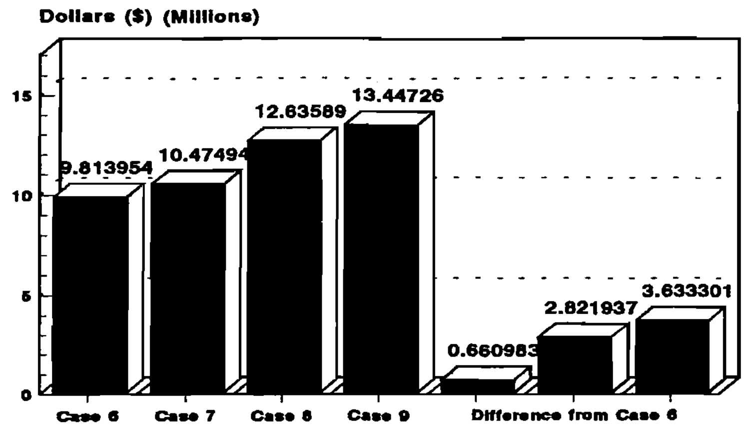
6.4.1 Summary of VENPLY Results

The net revenues from the four VENPLY case studies are: $ 9.813 M, $ 10.475 M, $ 12.636 M and $ 13.447 M for Cases 6, 7, 8 and 9, respectively. These net revenues together with their incremental increases over the revenue from Case 6 are shown in Figure 6-17.A. These increases in revenue are brought about by: (i) the capability of VENPLY to act as a second optimiser on an already optimised LOGPLY input; (ii) the production conditions (Cases 7 and 8); and (iii) the market (Case 9). These effects are discussed later in 6.4.2, 6.4.3 and 6.4.4. Veneer costs make most of the difference in revenue for all cases in which optimisation of veneer allocation can be attributed to different panel layup options and conditions assumed in those case studies. Veneer costs are; $ 14.88 M, $ 14.22 M, $ 12.04 M and $ 12.09 M for Cases 6, 7, 8 and 9 respectively, as shown also in Figure 6-17.B. The panel product revenue for Cases 6, 7 and 8 are equal but Case 9 results in a gain of an additional million dollars. Veneer downgrading can still occur in VENPLY, as in Case 9, but only with HCp veneers, since processing or allocating raw MXB veneers would result in two grades of veneer (HCp and MXB), as happened in Case 8 (Figure 6-18.A). The effect of veneer downgrading is further discussed in 6.4.5. The machine time allocation by machine centre is shown in Figure 6-17.C.

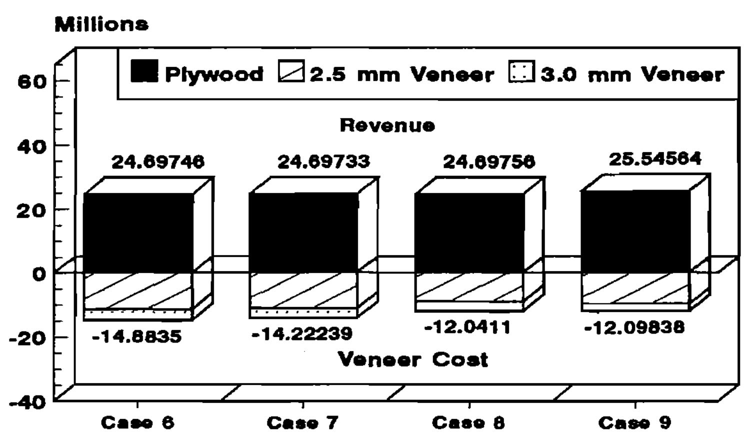
6.4.2 Effect of VENPLY as Second Optimiser

A further increase of $ 0.66 M in net revenue is a result of the soft optimisation created by VENPLY (Case 7) over Case 6, since Case 6 is a VENPLY version of the optimised LOGPLY Case 1 study, as pointed out earlier. The increase in net revenue

A. Net Revenue



B. Gross Revenue and Veneer Cost



C. VENPLY Machine Time Allocation

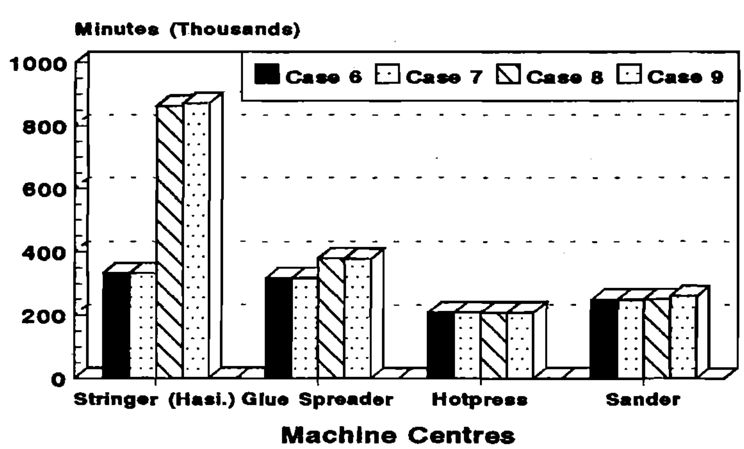


Figure 6-17. Summary of Results in 4 VENPLY Case Studies.

can attributed to the second optimisation using VENPLY and soft optimisation approach over LOGPLY in the same planning situation. The use of VENPLY as secondary optimiser beyond the already optimised LOGPLY cases is a very important factor in eliminating veneer downgrading activities in LOGPLY. In Case 6 alone, for example, the veneer cost-saving is $0.66 M, the difference in net revenues for Cases 6 and 7, as shown in Figure 6-17.A. Figure 6-18.A reveals that a substantial volume of Cp veneer is being downgraded in the optimally designed LOGPLY system (Cases 2, 4 and 5). The total value of these veneers in each case ranges from $ 1.94 M to $ 5.39 M, as shown in Figure 6-18.B. If lower grade veneers can be procured from other mills at half the price of Cp veneers, a considerable opportunity to save that is offered through tandem running of VENPLY and LOGPLY. An assumption is made that the downgraded veneers could be replaced by HCp and MXB veneers at $ 250 per cubic metre, the value of replacement or substitute veneers shown in Figure 6-18.C. The possible additional revenue that can be realised by implementing this strategy is shown in Figure 6-18.D. The additional revenue ranges from $0.84 M to $ 2.67 M. Although these additional revenues entail additional processing costs in direct and variable cost terms, realisable revenue will be assured from veneer substitution or veneer trading from mill to mill, in addition to preserving the opportunity value of veneers through their being saved for other product mixes. Thus, using the models in tandem provides an exciting prospect for decision-makers.

6.4.3 Effect of Production Condition

Comparing the results of Cases 7 and 8 illustrates explicitly how production conditions can significantly influence the profitability or opportunity losses in an operation. The opportunity cost can be as high as $ 2.16 M a year due to inefficient machines or poorly identified machine bottlenecks. The only difference between

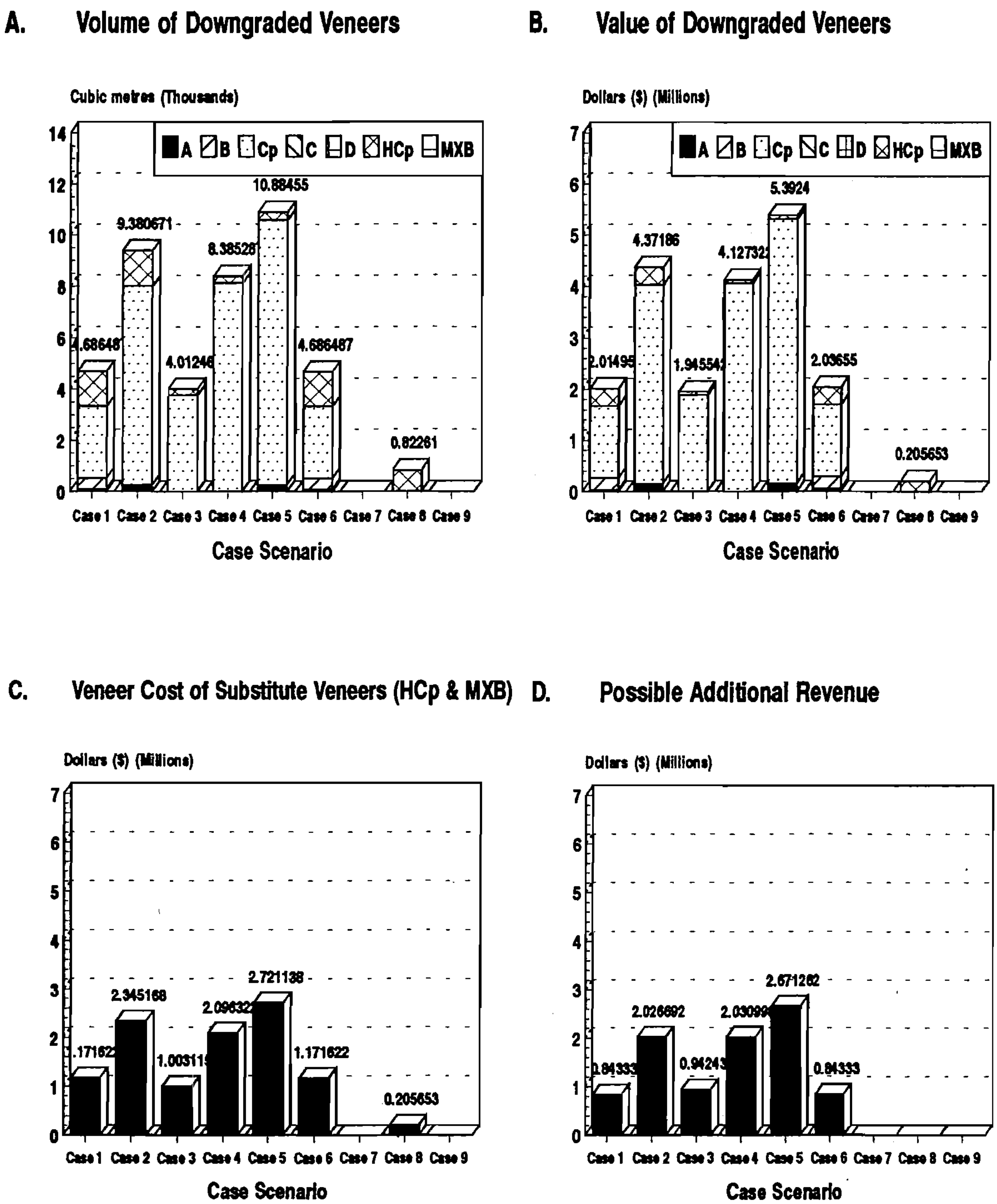


Figure 6-18. Volume and Value of Downgraded Veneers in LOGPLY and VENPLY Case Studies.

Cases 7 and 8 is the production constraint. No machine centre constraints are imposed in Case 8. Thus, the model can choose less costly or low grade veneers, since enough machine time is available to process them. Overtime is not an issue here when bottlenecks can be properly identified. Hence, labour costs or other direct costs could not be an issue. Case 8 used more raw multi veneer than did Case 7, which could be stringed to produce HCp and MXB. Figure 6-17.C shows how much stringer time is needed to process them. Eventually, more spreader time is also required since stringed corestock is slower to feed and produces assembled panels more slowly than full sheet corestock. The required glue spreader time is also shown in the same figure. But in the case of a real plant, these two machines are readily available; the stringer machine is operated for only half the shift hours on average and in two shifts only. Only one operator is required to operate it. In the case of the glue spreader, the plant being studied has two glue spreaders at present. One is mostly idle while the other is being used. The simulated stringer and glue spreader machine time requirement needed can be easily supplied.

6.4.4 Effect of the Market Condition

The effect of market conditions can be illustrated through comparing the results of Cases 8 and 9. The net revenue difference is $ 0.81 M. The only difference between Cases 8 and 9 is the market condition: in Case 9, the individual panel products according to thickness and grade were allowed to take maximum and minimum market quantities, 50 percent more for maximum and 50 percent less than in the production\market plan, except for 21 mm panels which were set at a maximum, namely the level of the production\market plan. There is veneer downgrading of HCp to MXB in Case 8, because the market condition gives some leeway in the production of relatively more profitable products, that can be exploited through taking the maximum and minimum quantities needed when a certain product is relatively unprofitable. There is no need to explain the importance of pricing and product layup options in determining profitability and generating incremental increases in net revenue, as explained in 6.2.3. However, opportunities to employ the models, especially VENPLY in its market-oriented modelling capability, can lead to improved decision-making.

6.4.5 Veneer Downgrading

The reason for and advantage in downgrading veneers were fully explained for the LOGPLY case studies in 6.2.7. However, veneer downgrading can also eventuate in VENPLY, if the model is used to optimise a given system. VENPLY was designed to accommodate well also veneer downgraded in certain situations, for instance when optimising a given set of veneers to be allocated in the traditional use of LP models. Veneer downgrading activities were not demonstrated in these examples, since all of them were designed as optimal systems. Veneer downgrading activities can be totally eliminated in VENPLY using the *de novo* programming approach and placing a penalty cost for downgrading, as shown in Cases 7 and 9 (Figure 6-18.A). The veneer downgrading activity in Case 8 was brought about in the design and structure of VENPLY, because in processing raw Multi's, two intermediate veneer products (HCp and MXB) were produced simultaneously as explained earlier.

6.4.6 Veneer Procurement

The greatest utility of VENPLY lies in its capability to determine the most profitable veneer allocation or procurement without downgrading, using the *de novo* programming approach with different situations. In Figure 6-19 the veneer allocations for Cases 6, 7, 8 and 9 are shown. In Case 7 (Figure 6-19.B) for instance, a production constrained case, the veneer procurement focused on the utilisation of full sheet veneers rather than on use of Multi's, because production rates for full sheet veneers are faster for most machine centres, especially for stringing and gluing. However, without any production constraints, as in Cases 8 and 9, the model used labour intensive veneer production techniques in favour of a lesser veneer cost, as shown in Figure 6-19.C & D. Thus, veneer allocation in different VENPLY case studies depends on different production and market conditions imposed. Hence, VENPLY can be used in all planning horizons, starting from strategic planning, for determining veneer production capacity down to tactical fortnightly scheduling of peeling veneer to meet veneer requirements in meeting market demands.

This chapter has explained the relevance of viewing veneer and plywood operations in a multi-dimensional approach using LP models. The inter-relationships with the log resource, production environment and market have been fully scrutinised using both LOGPLY and VENPLY. The advantages of designing an optimal system were fully demonstrated over and above the traditional use of models to optimise given conditions. The relevance of having a detailed structure to accommodate the utility of the model for scheduling and simulation purposes is demonstrated. Lastly, the capabilities of LOGPLY and VENPLY as material resource-oriented, market-oriented, manufacturing-oriented, real-time, and profit-maximising models were explored. The next and last chapter summarises the findings of this study, then draws some conclusions and recommendations on commercial processing, when utilising LOGPLY and VENPLY to address the overall needs of decision-making in veneer and plywood operations.

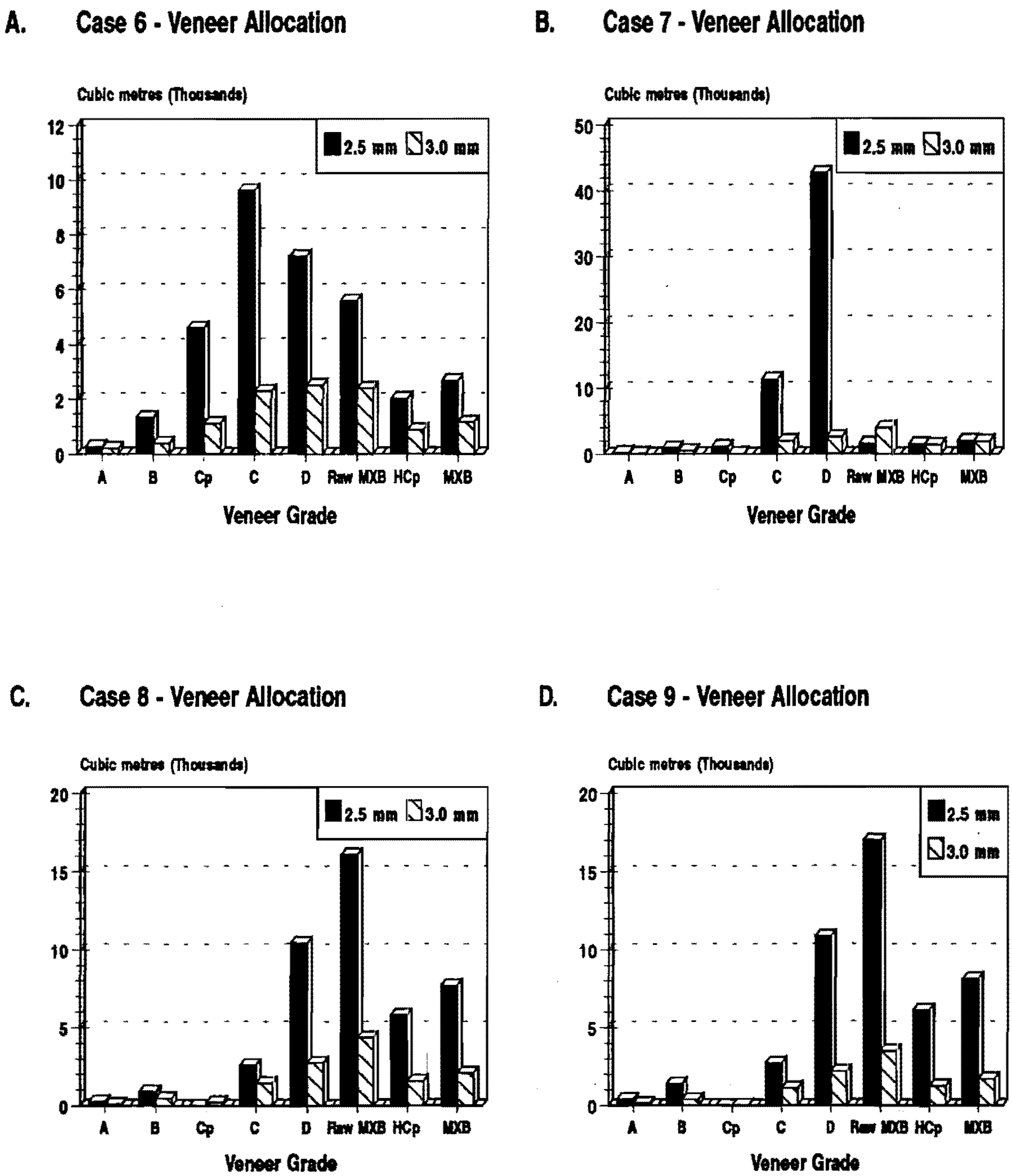


Figure 6-19. Veneer Allocation\Procurement of the 4 VENPLY Case Studies.

Chapter 7

Summary, Conclusions and Recommendations

7.1 Summary

This study examined methodologies for the formulation, implementation and use of linear programming (LP) models to address the global needs of decision-making in veneer and plywood operation. Problems of data collection for structuring efficient models were also addressed by conducting independent studies, (veneer recovery and time studies) to fully characterise the veneer and plywood operations.

Two resource production and marketing-oriented LP models, LOGPLY and VENPLY were developed. These two models worked in tandem to address effectively the need for decision making in the strategic, tactical, and operational planning levels that confront production and marketing managers in their aim to achieve greater profitability and, moreover, to control their operations effectively. These profit-maximising LP models were implemented in a spreadsheet, Quattro Pro 3.0, and in an add-on LP package, Beeline, in a microcomputer (PC) environment that can be used as real-time decision support systems which: (1) simplify and disguise the technical complexity of the model, (2) eliminate the difficulty of routinely implementing mathematical models and (3) create a more effective communication mechanism between the routine use of models and managers' decision-making. The spreadsheet environment, furthermore, addresses the perennial problem of a continuously changing environment and the need for frequent alterations of technological and resource coefficients, for example: (i) the variability of log resources; (ii) variable conversion factors and prices; (iii) technological advancement in machine capabilities that alter machine productivities and bottlenecks over short periods of time; (iv) a multi-skilled labour force that could be shifted anytime to different machine centres to improve any unproductive machine centre and to match the dynamic market scenario for wood panels affecting plywood prices and ordered quantities. The implementation of the systems in a spreadsheet environment provide managers and decision makers with the ability to simulate production and market conditions routinely, by updating the aforementioned coefficients without the help of outside research personnel.

LOGPLY deals with converting logs to plywood. This aspect of the managerial problem involves the allocation of quantities of logs from a choice of different sources, log types and log dimensions to produce desired mixes of veneer for the product mix. Intermediate activities consist of peeling the logs to produce veneers of different thicknesses and grades,(together with byproducts of hog fuel and log cores), splicing less than full width veneers (upgrading random width veneers, multiples and fishtails, into core veneers), and finally allocating veneers to markets without further processing (veneer sales), if profitable, and to various layup options for making a range of plywood products. In this model, therefore, veneers by grade and thickness are treated as intermediate products as well as commodities for the market. The model has a downgrading mechanism for veneer which maintains a zero level of veneer inventory. This conforms to the principle of Materials Requirement Planning (MRP), the framework for scheduling of which is discussed in explaining the use of LOGPLY and VENPLY as scheduling tools. Machine productivity constraints, starting with the rotary lathe and extending to the sander, are placed in the model to characterise the realities of veneer and plywood constrained production. The machine rates used in the model coefficients were the results of time and motion studies conducted as part of the study. The final activities consist of allocating plywood by panel thickness and grade to relevant markets and veneer sales. With regard to plant capacity planning, three capacity options were included in the model: (i) log input, (ii) veneer output (veneer sales and plywood layup) and (iii) plywood product output. The three capacity options provide the necessary flexibility to meet what managers wish to achieve in planning and to identify options where managers can see that more data should be available, and where more precise and greater control over the operation is needed in order to reflect reality better.

VENPLY deals simply with converting veneers to plywood products. It is a subset of LOGPLY. The primary input of the model is the dry untrimmed veneer inventory by grade and thickness, rather than the mix of log types that needs to be used. This model can thus cope with a lack of recovery data or inaccurate recovery data inputs that are essential to run LOGPLY. Running LOGPLY for tactical planning purposes with inaccurate recovery data and poorly calibrated recovery figures could lead to a major discrepancy in characterising the conversion of volumes of logs-to-veneers and veneers-to-plywood compared to actual operations. This problem can be overcome, however, using VENPLY as a second optimiser to allocate properly the veneer outturn from the actual mix of logs that is available or recommended by LOGPLY. The structure of the model is very similar to LOGPLY, the only difference being that the model starts with veneer. The veneers are thus treated as both a raw material input and at the same time a commodity for the market. The machine constraints in VENPLY start with the splicer and end up with the sander. The same plywood layup options and marketing constraints as in LOGPLY are used in VENPLY.

LOGPLY and VENPLY were formulated in such a way that *soft* optimisation or a *de novo* programming approach can be accommodated, where resource capacities are viewed as flexible variables instead of simply firm constraints. This approach recognises that not all constraints should be regarded as *hard* (fixed RHS quantities to be allocated); some are assumed to be *soft*, the type of which can be subsequently determined through analysis. This approach has the advantage of designing an optimal system, rather than optimising a given fixed system, the traditional LP problem. The soft optimisation approach enhanced the capability of LOGPLY and VENPLY as strategic planning tools for managing plywood production. LOGPLY can determine the log input subset while VENPLY veneer can determine the veneer input subset for given market demands. This approach can shed new light and provide fresh insights into the gloomy future for the radiata veneer and plywood industry in New Zealand that has been portrayed in the 1992 New Zealand Forest Industries Strategy Study (Edgar *et al.*, 1992).

LOGPLY allows the user to identify the right log type proportion to be procured or processed and the right combination of different veneer thicknesses to be peeled from these logs to satisfy the forecasted product-mix demands. The model maximises the value of logs to end-product, therefore, rather than the value of the logs in terms of intermediate veneer products. The decision to downgrade veneers taken by the model in the different runs allows the modelling to optimise the economic returns of the whole production process. The model can also provide true values (shadow prices) of logs and veneers in terms of their worth to the production. In VENPLY, the prices of the veneer grade are supplied prior to the run. Veneers are the primary inputs of this model and so it deals with only one part of the whole process. VENPLY has its own strength, however, the main ones being (i) it is a good simulation model for the proper allocation or procurement of veneer grades and thicknesses without downgrading to satisfy the material requirements of the product mix using the *de novo* approach. Although the model employs a downgrading mechanism to accommodate the traditional use of the model to allocate a fixed volume of veneers to produce the product mix; (ii) it serves as a second optimiser for the outturn of veneers (veneers on the floor) from the processed logs, which have been determined or procured using LOGPLY; and (iii) it is a scheduler to be used in fortnightly planning to allocate veneers and machine times needed to produce the required product mix over that planning horizon. Scheduling, it is explained, is one of the urgent needs of the plywood industry that has to be faced daily for a plant to survive.

One radical improvement that has eventuated as a direct consequence of this type of formulation is incorporation of the marketing aspect. Market constraints in terms of panel thickness and grade provide for a market-oriented manufacturing approach. This concept involves responding to market needs through tailoring manufacturing by designing what log resource should be purchased and how these logs should be peeled into different proportions of veneer thickness to produce the product mix. This is in contrast with the traditional use of LP models in which the product mix is optimised through a fixed log resource input and aggregate log criteria. This latter problem was also addressed through adopting the *de novo* programming approach and through refinement of the model structure in the resource constraints with the introduction of the concept of sorting and classifying logs according to small end diameter (SED) class. The LOGPLY models can have very detailed resource constraints in terms of log source, type and diameter class. SED class ranges adopted in this study were (a) 350 - 390 mm, (b) 401 - 450 mm, (c) 460 - 500 mm and (d) 510 - 620 mm. Recovery studies were conducted to determine the conversion factor of logs according to the SED class, source and type of log and veneer thickness. The technical and economic advantages of having veneer recovery information of this kind have been simply demonstrated. The results of the recovery study were employed in formulating the models to produce considerably improved sensitivity of managerial control. The advantage of sorting and classifying logs in routine operations is fully discussed. Sorting and classifying logs into diameter classes together with the *de novo* approach, "change-constrained" programming, the traditional use of LP model, parametric analysis and even probabilistic extensions to the model are identified as major, low-cost ways of improving veneer and plywood operations.

Analysis of recovered veneer yields from logs indicated that there is also a statistically significant though weak effect of small end diameter class on veneer recovery for both unpruned and pruned logs. The variability of the yield could be attributed not only to the measured variables (log sourcing, log type and small end diameter), but also to other factors such as tree age, pruning regime, defect core diameter, cross-sectional circularity and resin pockets, which latter factors are hard to measure and quantify. These factors together with others attributed to plant design (e.g. equipment and production crew practices), were also relevant in explaining the variability of results. The trends of veneer recovery in relation to log source, log type, small end diameter, peel veneer thickness, veneer grade grouping and individual veneer grades were established. The byproducts (log core and hog fuel) and their interrelationship to aforementioned factors were also discussed. A further interesting possibility is that values and trends established in this study could be used as vital marketing information on the potential of export pruned and unpruned logs as peelers logs to Korea and Southeast Asia. The main object of the recovery study, however, was to have a benchmark of data to use as coefficients for the LP plant models and to show the potential for recording recovery data by diameter class.

In the case studies described and analysed, clear illustrations are provided to show how LOGPLY and VENPLY can be used in the following areas: log procurement; pricing and allocation; determination of optimal product mix (veneer and plywood); product costing and pricing; plant capacity planning; evaluation of machine performance; scheduling production; coordination of marketing; and investment options.

The concept of a standard formulation was introduced, with emphasis on a homogeneous standard of measurement that was consistent among variables (e.g. all volumes are in cubic metres and all time is in minutes). All the coefficients are espressed in only these two units: logs, veneers and plywood are expressed in cubic metres; machine rates are in cubic metres per minutes. The advantages of this approach are: (i) avoid confusion on how to relate to the unit of measure from one activity to the other during the formulation of the model and interpretation of results; (ii) consistency of conversion units among activities e.g. veneer to plywood, veneer upgrading and falldown yield downgrading were easily achieved. These activities often led to a discrepancy in results for previous formulations, as veneers were often measured in surface metres, plywood in cubic metres and then units reconciled to the thinnest plywood thickness for the coefficients in the LP model. A third advantage, therefore, was (iii) easy interpretation of results so that a straightforward analysis of the output can be achieved.

The spreadsheet environment and spreadsheet-based optimisation package greatly simplified the model formulation and implementation of the multicoupled and angular or block-diagonal structures in LP models. These types of structures are the characteristics of large-scale LP models to which LOGPLY and VENPLY may belong. The revised simplex algorithm of Beeline 1.24 and 1.52 is sufficient to solve LOGPLY and VENPLY. However, the Lower-Triangular and Upper-Triangular LU Decomposition algorithm (Bartels-Golub) of the very recent Beeline 1.61 capability could speed up elimination of artificial constraints through use of the so called "crushing method".

With regard to portability, LOGPLY and VENPLY can be run on several platforms (e.g. Unix, OS/2, DOS, Macintosh System), the choice of which should not be a problem. Recently the Unix version of Lotus 1-2-3 version 1.1 was released for the mainframe. With Lotus 1-2-3 spreadsheet format, WKS became the standard or added feature of almost all spreadsheet packages in PCs' (DOS, OS/2 2.0 and Windows 3.1) and MacIntoshes'. The hardware requirement to run the system would also not be a problem. IBM PC compatible laptops (in A4 paper dimension) are sufficient to run the system easily and promptly. The subnotebook (in A8 paper diagonal dimension) was recently released. But the palmtop technology is now here (Hewlett Packard, HP 95-LX which weighs 312 grams), and the first palmtop with a built-in Lotus 1-2-3 version as a standard feature has been released . Apple will soon release, early in 1993, its counterpart - the Newton, penbased palmtop. With these advances in computer technology, decision tools are very much within the pocket and at the fingertips of managers.

Lastly, the prime benefit and gain on the use of the system in addition to the economic returns and means of obtaining direct solutions to the problem, are the management insight derived from the results and use of the system to indicate how production and market factors affect the profitability of this industry.

7.2 Conclusions

The research conducted for this study has given rise to the following conclusions.

1. Veneer and plywood operation can be successfully represented in a linear programming model and can be arranged in the form of a decision support system (DSS) framework that can be routinely used by managers. The DSS framework improves the communication between the modelling and managers' needs with little or no input from outside researchers. The system works and fully addresses the diverse needs of decision making in both the production and marketing facets of the operations.
2. The veneer and plywood LP models are most successful if they include market demand constraints by panel thickness and grade, and also if the range of log small end diameter classes, the source of logs and the log type are recognised. All these factors bear heavily on economic sensitivities.
3. The concept of standard units of measure in modelling simplifies the formulation and implementation of the model also facilitates the

interpretation of results. The units used are the same units that production and marketing managers employ in operations. Thus, managers should find it relatively easy to digest and interpret the results of modelling their operations.

4. The soft optimisation or *de novo* programming approach enhances the ability of LOGPLY to choose the most appropriate mix of logs, while that for VENPLY and LOGPLY allows one to determine the best veneer requirement to produce the desired product mix.

   a). Taking this approach resulted in increasing the profitability of the mill case study by up to 43 percent over the traditionally optimised case in LOGPLY (Case 5 vs. Case 1).

   b). In VENPLY the further increases in profitability have reached 37 percent (Case 9 vs. Case 6) with no veneer downgrading being necessary in matching the best veneer combination to produce the product mix.

5. Change-constraints programming successfully handled the problem of randomness in resource values such as log availability, available machine time and market demands. This approach, through altering the RHS values also allows machine bottlenecks to be scrutinised and evaluated, and the effects of having a new or replacement capacity on profitability of the operation to be determined. Moreover, this method also accommodates simulation of different scenarios in the two models through finding the right combination that could be best or most realistic for satisfying both production and market demand requirements

6. VENPLY and LOGPLY belong to a type of large-scale linear programming model that is characterised by multicoupled and angular or block-diagonal structures, a series of independent matrix subsystems that are tied or coupled together by a common set of constraints and variables, with relatively more constraints than variables. In the case of LOGPLY, however, the numbers of constraints are almost equal to numbers of variables. But LOGPLY has three independent activities: allocating the logs into different veneer thicknesses; allocating the veneers into different layup options and veneer sales; and satisfying market demands.
7. The *de novo* programming approach applied in LOGPLY and VENPLY can be solved using the revised simplex algorithm in Beeline versions 1.24 and 1.52 without any problem. However, to obtain solutions in less time, the use of the LU decomposition algorithm in Beeline 1.61 may be advisable.
8. Results also indicate that greater profit could be achieved by processing bigger diameter logs with higher yield despite their higher purchase costs.
9. The value of logs reflected in the shadow prices and reduced costs of the different LOGPLY runs always depends on the product mix the logs are intending to serve. The shadow price of logs could also be viewed as the opportunity gain for every cubic metre available for processing. This value could be used for log pricing and log purchasing negotiations. The reduced cost is the penalty cost of processing a specific log to produce a specific veneer thickness and is equivalent to

the reduction in the objective function value for every unit (e.g. cubic metre) of non-basic log input used or processed by the mill.

10. Log price and recovery factors both have significant effects on log allocation and selection of logs. There is a dynamic relationship between these factors in the two LP models presented here. Changes in log price, however, would not adversely affect LOGPLY objective function values in the sense that log allocation is dependent purely on veneer requirements by grade derived from a specific log type and diameter class to produce the product mix and machine time involved in different machine centres.

11. In the different scenarios evaluated in this study using LOGPLY, it was ascertained that the veneer and plywood plant should not be fed with just pruned logs, but with a combination of pruned and unpruned logs unless there were considerable demands for A & B veneers at the right price. The log mix should range from 40 % pruned : 60 % unpruned to 21 % pruned and 79 % unpruned, based on the assumed market demands by panel grade and thickness. The numerical examples do not actually represent actual conditions, but are considerably modified so as to protect commercially sensitive information. Nevertheless, it can be concluded that there is no need for 100 % pruned logs, as assumed by Edgar *et al.* (1992) in their feasibility study. The results of this study indicate that veneer and plywood production in New Zealand could be one of most profitable wood processing investments, provided that log type proportions are properly identified and recognised in deciding on intended or planned product mixes for the markets through

applying the concept of market-oriented manufacturing using veneer and plywood LP models.

12. Using LOGPLY, the most costly constraining factor in production is the dryer. Thus, any improvement in terms of its available time will improve the profitability of the plant. Using VENPLY, the spreader appeared to hinder productivity in the plywood section. The dual values,or shadow prices, of the different machines can be shown or elevated using "change constraints" programming. The method allows manipulation of the RHS of the different machine constraints, thus forcing one machine to be a bottleneck so as to derive its shadow price.

13. In general LOGPLY and VENPLY can fully address the problems relating to the following.

    a) *Log procurement, price, mix and allocation.* LOGPLY can give managers the ranking of logs by their source, type, diameter class according to their production potential value. The ranking can be used for, (i) competitive log procurement strategy e. g. ordering desirable logs and paying suppliers a premium price, (ii) log price negotiation, and (iii) log swapping strategy between a plywood plant and sawmills. Decisions on log mix proportions can be much clarified. At the tactical planning level, LOGPLY allocates efficiently the available logs by log source, type, diameter class and peel thickness that is needed to produce the desired product mix.

    b) *Veneer valuation.* The real value or worth of veneer by grade and thickness in relation to veneer selling price, plywood prices, production cost and other factors can be determined.

c) *Veneer requirement.* The exact veneer requirement by grade and thickness to produce the product mix can be easily determined, based on presumed conditions (with or without veneer grading).

d) *Optimal layups and product mix determination.* The best layup option to manufacture a specific product is supplied in the solution. The profitability or loss from manufacturing a certain product in relation to the whole product mix can also be determined.

e) *Evaluation of new products.* Prices of new products can be drawn from the solution of LP models. The preset prices of new products, moreover, can be properly gauged, calibrated and analysed to see if individual products are worth producing for the market. Prices of a new product can be adjusted, if needed and a subsequent run of the model will determine how the new product or adjusted prices compare with the rest of the products.

f) *Plant capacity planning.* Three levels of plant capacities are being addressed in the models, namely; (i) log input capacity, (ii) veneer output capacity and (iii) plywood output capacity to suit the planning, tactical and operational planning needs of both production and marketing operations.

g) *Machine performance.* All the pertinent machine centres are included in the model; thus, any bottleneck in the operation can be determined. Using the change-constraints programming approach, performance of any one machine can be analysed with respect to the profit it contributes to the operation.

h) *Production scheduling and control.* Material requirement and machine time for specific production runs can be drawn from the solutions, thus allowing the question on when and how to manufacture the product to be addressed;

i) *Production and market coordination.* The concept of market-oriented manufacturing introduced in this study can generate improved coordination between the two operations;

j) *Marketing.* Marketing managers can deduce what products are most profitable to market and what discounts to offer as well as what product mix to market to contribute a greater profitability to the operation; and

k) *Investment options.* Log procurement strategies, plant capacity and machine capacities are addressed in the two models. Management can obtain useful insights into where to invest their money in order to have greater profitability for the operation.

15. The spreadsheet environment simplifies model formulation, implementation and interpretation of the multicoupled structure of the veneer and plywood LP models, LOGPLY and VENPLY. The lengthy task of writing a matrix generator program has been eliminated. The spreadsheet LP model can be easily debugged for inconsistency in the solution, it has the flexibility to accommodate additional constraints and updates of the technological and resource coefficients, and it has proved to be easy to evaluate different business scenarios and management approaches in successive runs.

16. Implementation of the LP models on spreadsheets in a PC environment has resulted in the development of a real-time decision support system tool which is a market-oriented optimisation modelling system for strategic, tactical and operational planning for production and marketing. The modelling simplifies the formulation, implementation and interpretation by introducing a concept of a standard formulation and measurement to produce consistency among variables. It also accommodates the *de novo* programming approach, change constraints programming and traditional use of the LP models which are all vital analysing in the economics of the operations. The incorporation of diameter class in the log resource and market constraints by thickness and grade together with the *de novo* programming approach gave an added dimension for LP modelling log procurement which has not yet been examined in previous LP modelling studies. Real-time aspects of the system can respond to a fortnightly time horizon or even a daily one to address fully the need for a scheduling as well as an optimising tool in the production, again an aspect not previously catered for. The system, if adopted, would have a major impact through better planning, coordination and communication between production and sales personnel. The current laptop and imminent palmtop technology with extended and expanded memory that transcends the 640 Kb memory barrier and 40 Mb hardisk can provide the necessary hardware for decision makers to employ VENPLY and LOGPLY readily at very reasonable cost.

7.3 Recommendations

The system and the individual models developed here are shown to be powerful tools for revealing potential opportunities for veneer and plywood production and for marketing. However, to capture these opportunities fully a committed plan of action, especially in data collection, is necessary to permit this system to work effectively. This system, as with any other system that is data-driven, requires good data. It is recommended that, as set out below, data relevant to this program should be prepared or collected regularly to ensure quality of performance and to allow proper calibration of the model against reality. This investment is crucial in order to reap fully the opportunities and insights offered by the system. There is also a need to refine the technical and resource coefficients continually, due to the stochastic nature of the variables involved in the operation.

The following data-base should be gathered, prepared, analysed and upgraded regularly:

1. veneer recovery data by thickness, veneer grade (both full sheets and multiples) from logs by source, type and small end diameter class;
2. inventory policy for finished products and procurement policy for raw materials;
3. operating plans (production and marketing) keyed to the financial budget should be reviewed fortnightly for scheduling and control, (quarterly for tactical planning, and annually for strategic planning);
4. a record of the falldown pattern of panels after pressing;
5. machine rates and available machine times; and
6. direct costs of processing, separately from indirect costs.

In addition, mill managers should place greater emphasis on procuring the most appropriate logs. A management position should be created and dedicated person should oversee this operation, to coordinate properly the sorts of logs to be procured in liaison with the material-planner controller. The material-planner controller should have qualifications over and above the production foremen and be very knowledgeable in all aspects of the production as well in operational research techniques.

With regard to further refinement of the system and the models, knowledge-based programming may have some potential for model formulation and interpretation of results in future. Currently, operational research tools and knowledge-based, or expert systems, are still somewhat apart. Knowledge-based programming operates through ruled-based principles and works on symbolic pattern matching, while operational research tools (including LP) deal with algorithmic processes and work in numerical forms. Object oriented programming languages such as C^{++}, Smalltalk, etc. show some potential to do symbolic and numeric data processing but have not yet matured enough to tackle the problems of what operational researchers want. Nevertheless, with the advancement of operating systems like ACE (proposed operating system for mainframes, Sunsparc, PC and Mac), Talligent (IBM and Apple project) and recently Cairo (Apple and Microsoft), a hybrid of programming languages or packages that should have the capabilities to model this need would emerge. According to Apple and Microsoft, Cairo could link data wherever located, and is not application dependent. Applications and data, therefore, could be compatible in both the PC and Mac platforms.

Finally, it is recommended that the methodologies demonstrated should be applied and put to use not only in veneer and plywood plants but could be adapted also to other processing operations such as the sawmill industry. The scenarios being presented here may be slightly different from the conditions of every veneer and plywood plant, but the management techniques derived from this study as well as the concepts and methods introduced, are very applicable to their operation. In the case of the sawmilling industry, however, the model structures might be different due to plant design and different processes that logs undergo, but the breakdown from logs to lumber and consequent processing would be parallel to activities in the veneer and plywood operations. Thus, the applicability of the concepts and methods discussed in this study should improve how businesses are managed to optimise returns rather than material recovery.

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Appendix A. Survey Questionnaire

Preliminary Survey Questionnaire
Veneer and Plywood Modelling
(3 December 1990)

I. General Information

1. Plant Name:____

2. Location:____

3. Year Established:____________________________________

4. Plant Rated Capacity

   a). Log Input __________________________ (m^3/year)

   b). Veneer Production____________________ (m^3/year)

   c). Plywood Production___________________ (m^3/year)

II. Log Supply Categories

Do you use this log grade classification below in categorising logs to be processed in the Plymill?

Log Grade	Small End Diameter (mm)	Description	Source Categories
P1	400+	Pruned	
P2	300 - 399	Pruned	
S1	400+	Unpruned	
S2	300 - 399	Unpruned	
S3	200 - 299	Pruned or Unpruned	
S4	150 - 199	Pruned or Unpruned	
L1	400+	Unpruned	
L2	300 - 399	Unpruned	
L3	200 - 299	Unpruned	
L4	150 - 199	Unpruned	
I	300+	Pruned or Unpruned	

If not, please supply the classification indication the log grade, its diameter class, source, etc.

Log Grade	Diameter Class (mm)	Description	Source Categories

III. Veneer Categories

i). Do you peel the following veneer thicknesses?

a). 2.5 mm

b). 3.0 mm

c). Others __________

____

ii). Do you classify your veneer into these grade categories?

A, B, Cp, C, D, E, S

Are Fishtails E or S grade?

iii). Veneer moisture - average and range

	Moisture Content (MC) %	Range
Sapwood	__________	__________
Heartwood	__________	__________

IV. Product Categories

A). Panel Thickness : 7.5 mm

Grade		Layup Options	V. Thickness	Volume (m3/year)	Price ($/m3)	Remarks
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					

B). Panel Thickness : 9.0 mm

Grade		Layup Options	V. Thickness	Volume (m3/year)	Price ($/m3)	Remarks
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	1					
	2					
	3					
	4					
	1					
	2					
	1					
	2					

C). Panel Thickness : 12.5 mm

Grade		Layup Options	V. Thickness	Volume (m3/year)	Price ($/m3)	Remarks
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	1					
	2					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					

IV. Product Categories (Con't.)

D). Panel Thickness : 15.0 mm

Grade		Layup Options	V. Thickness	Volume (m3/year)	Price ($/m3)	Remarks
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					

E). Panel Thickness : 17.5 mm

Grade		Layup Options	V. Thickness	Volume (m3/year)	Price ($/m3)	Remarks
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					

IV. Product Categories (Con't.)

F). Panel Thickness :21.5 mm

Grade		Layup Options	V. Thickness	Volume (m3/year)	Price ($/m3)	Remarks
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					
	1					
	2					
	3					
	4					

V. Production Categories

A). Lathe & Clipper Net Output Rate

Log SED Class	Output Rate		
(cm)	(m3/h)	(m3/min)	(min/m3)

B). Dryer Rate

Log SED	Ave. Gross		2.5 mm	Dryer Rate		3.0 mm	
Class	Veneer Volume	*Dryer rate:*	*m3/h*		*Dryer rate:*	*m3/h*	
(cm)	(m3)	(m3/h)	(m3/min)	(min/m3)	(h/m3)	(m3/min)	(min/m3)

C). Stringer/Splicer Output Rate

Veneer Thickness : 2.5 mm					
Veneer Grade	Rate @ 8 hours	Sheet Volume	Output Rate		
	(Sheet)	(m3)	(m3/h)	(m3/min)	(min/m3)
Veneer Thickness : 3.0 mm					
Veneer Grade	Rate @ 8 hours	Sheet Volume	Output Rate		
	(Sheet)	(m3)	(m3/h)	(m3/min)	(min/m3)

D). Glue Spreader Rate

Panel	Stringed/Spliced Corestocks				Full Sheet Corestocks			
Thickness	Output Rate				Output Rate			
(mm)	(Panel/h)	(m3/h)	(m3/min)	(min/m3)	(Panel/h)	(m3/h)	(m3/min)	(min/m3)

E). Hotpress & Trimsaw Rate

Panel	Volume			Output Rate			
Thickness	Panel Volume	Panels/Setup	Volume/Setup	(m3/8 h)	(m3/h)	(m3/min)	(min/m3)
(mm)	(m3)	(Panel)	(m3)				

F). Sander & Stacker Rate

Panel Thickness	Panel Size	Panel Volume	Output Rate			
(mm)	(m2)	(m3)	(Panel/h)	(m3/h)	(m3/min)	(min/m3)

Appendix B. Log Supply Specifications

I. CB logs - NZFC Unpruned Logs (Cater-Beddison)

Log Length	5.15 m +/- 5 cm
Log Diameter	Minimum 35 cm SED
	Maximum 80 cm LED
Knots	Maximum diameter 15 cm
Straightness	1/4 SED / 2.4 m
Roundness	Smallest (D1) - Longest (D2) =< 7 cm
Pith	It must be contained within the middle third log diameter.
Butts	Flutes and Creases must not exceed 5 cm
General	No rot or stain
	No machine damage
	No splits
	No slovens
	Grade on every log
	Grade on every log

II. UP logs - NZFP Unpruned Logs

Log Length	5.20 m +/- 5 cm
Log Diameter	Minimum 35 cm SED
	Maximum 80 cm LED
Knots	Maximum diameter 7 cm
Straightness	Maximum 5 cm sweep over 3 m
Roundness	Smallest (D1) - Longest (D2) =< 7 cm
	Smallest (D1) - Longest (D2) => 7 cm (Unacceptable)
Pith	It must be contained within the middle third log diameter.
	If not, the log will be taken back by NZFP
Butts	Flutes and Creases must not exceed 5 cm
General	No rot or stain
	No machine damage
	No splits
	Crew # one end of log
	Felling date 1 in 10 logs
	No slovens
	Grade on every log
	No coathangers

III. PP logs - NZFP Pruned Logs

Log Length	5.20 m +/- 5 cm
Log Diameter	Minimum 35 cm SED
	Maximum 80 cm LED
Straightness	Maximum 5 cm sweep over 3 m
Roundness	Smallest (D1) - Longest (D2) =< 10 cm
	Smallest (D1) - Longest (D2) => 10 cm (Unacceptable)
Pith	It must be contained within the middle third log diameter.
	If not, the log will be taken back by NZFP
Butts	Flutes and Creases must not exceed 5 cm
General	No rot or stain
	No machine damage
	No splits
	Crew # one end of log
	Felling date 1 in 10 logs
	No slovens
	Grade on every log

Appendix B. (Con't.)

IV. TPB logs - Tasman Pruned Butt Logs

Log Length	2.60 m +/- 5 cm
Log Diameter	Minimum 35 cm SED
	Maximum 80 cm LED
Straightness	Maximum 5 cm sweep over 3 m
Roundness	Smallest (D1) - Longest (D2) =< 10 cm
	Smallest (D1) - Longest (D2) => 10 cm (Unacceptable)
Pith	It must be contained within the middle third log diameter.
Butts	Flutes and Creases must not exceed 10 cm
General	No rot or stain
	No machine damage
	No splits
	Crew # one end of log
	Felling date 1 in 10 logs
	No slovens
	Grade on every log

V. MP logs - CHH Pruned Logs (Mohaka)

Log Length	5.15 m +/- 5 cm
Log Diameter	Minimum 35 cm SED
	Maximum 80 cm LED
Straightness	Maximum 5 cm sweep over 3 m
Roundness	Smallest (D1) - Longest (D2) =< 7 cm
	Smallest (D1) - Longest (D2) => 7 cm (Unacceptable)
Pith	It must be contained within the middle third log diameter.
Butts	Flutes and Creases must not exceed 5 cm
General	No rot or stain
	No machine damage
	No splits
	Crew # one end of log
	Felling date 1 in 10 logs
	No slovens
	Grade on every log

VI. RP logs - CHH Pruned Logs (Rukomoana)

Log Length	5.15 m +/- 5 cm
Log Diameter	Minimum 35 cm SED
	Maximum 80 cm LED
Straightness	Maximum 5 cm sweep over 3 m
Roundness	Smallest (D1) - Longest (D2) =< 7 cm
	Smallest (D1) - Longest (D2) => 7 cm (Unacceptable)
Pith	It must be contained within the middle third log diameter.
Butts	Flutes and Creases must not exceed 5 cm
General	No rot or stain
	No machine damage
	No splits
	Crew # one end of log
	Felling date 1 in 10 logs
	No slovens
	Grade on every log

Appendix C. Machine Production Rates

I. Lathe & Clipper Net Output Rate

Log SED Class	Output Rate		
(cm)	(m3/h)	(m3/min)	(min/m3)
35 -39	12.07	0.201	4.97
40 -45	17.89	0.298	3.35
46 -50	22.56	0.376	2.66
51 - 62	27.16	0.453	2.21

II. Dryer Rate

Log SED Class	Ave. Gross Veneer Volume		2.5 mm	Dryer Rate	3.0 mm		
		Dryer rate is 11.88 m3/h for 2.5 mm veneers			*Dryer rate is 12.10 m3/h for 3.0 mm veneers.*		
(cm)	(m3)	(m3/h)	(m3/min)	(min/m3)	(h/m3)	(m3/min)	(min/m3)
35 -39	0.511	23.234	0.39	2.58	23.656	0.39	2.54
40 -45	0.606	19.613	0.33	3.06	19.969	0.33	3.00
46 - 50	0.657	18.083	0.30	3.32	18.412	0.31	3.26
51 - 62	0.719	16.515	0.28	3.63	16.815	0.28	3.57

III. Stringer/Splicer Output Rate (Hasimoto)

Veneer Thickness : 2.5 mm					
Veneer Grade	Rate @ 8 hours	Sheet Volume	Output Rate		
	(Sheet)	(m3)	(m3/h)	(m3/min)	(min/m3)
Clear Multi's (HCp)	1400	0.0072	1.260	0.0210	47.62
Multis (MXB)	1200	0.0072	1.080	0.0180	55.56
Veneer Thickness : 3.0 mm					
Veneer Grade	Rate @ 8 hours	Sheet Volume	Output Rate		
	(Sheet)	(m3)	(m3/h)	(m3/min)	(min/m3)
Clear Multi's (HCp)	1400	0.00864	1.512	0.0252	39.68
Multis (MXB)	1200	0.00864	1.296	0.0216	46.30

IV. Glue Spreader Rate

Panel Thickness	Hasimoto Stringed Corestocks				Full Sheet Corestocks			
	Output Rate				Output Rate			
(mm)	(Panel/h)	(m3/h)	(m3/min)	(min/m3)	(Panel/h)	(m3/h)	(m3/min)	(min/m3)
7.5	300	6.48	0.11	9.26	420	9.07	0.15	6.61
9.0	300	7.78	0.13	7.72	420	10.89	0.18	5.51
12.5	150	5.40	0.09	11.11	210	7.56	0.13	7.94
15.0	150	6.48	0.11	9.26	210	9.07	0.15	6.61
17.5	100	5.04	0.08	11.90	140	7.06	0.12	8.50
21.0	100	6.05	0.10	9.92	140	8.47	0.14	7.09

Note: Glue spreader rate is good for one spreader only.

V. Hotpress & Trimsaw Rate

Panel Thickness	Volume			Output Rate			
	Panel Volume	Panels/Setup	Volume/Setup	(m3/8 h)*	(m3/h)	(m3/min)	(min/m3)
(mm)	(m3)	(Panel)	(m3)				
7.5	0.0216	50	1.08	78	9.75	0.1625	6.15
9.0	0.0259	50	1.30	83	10.38	0.1729	5.78
12.5	0.0360	50	1.80	86	10.75	0.1792	5.58
15.0	0.0432	50	2.16	86	10.75	0.1792	5.58
17.5	0.0504	50	2.52	85	10.63	0.1771	5.65
21.0	0.0605	50	3.02	90	11.25	0.1875	5.33

** Rates supplied by CHH Management*

VI. Sander & Stacker Rate

Panel Thickness	Panel Size	Panel Volume	Output Rate			
(mm)	(m2)	(m3)	(Panel/h)	(m3/h)	(m3/min)	(min/m3)
7.5	1.2 x 2.4	0.0216	250	5.40	0.09	11.11
9.0	1.2 x 2.4	0.0259	250	6.48	0.11	9.26
12.5	1.2 x 2.4	0.0360	250	9.00	0.15	6.67
15.0	1.2 x 2.4	0.0432	250	10.80	0.18	5.56
17.5	1.2 x 2.4	0.0504	250	12.60	0.21	4.76
21.0	1.2 x 2.4	0.0605	250	15.12	0.25	3.97

Appendix D. Article about VENPLY (LOGPLY)

COMPUTERS & ELECTRONICS

Software enhances forestry operations

Recent computer package developments and updates from the Logging Industry Research Organisation and School of Forestry are tailored to New Zealand forest industry conditions, explains Vivien Edwards.

Venply helps with ply log purchase

When manufacturing plywood, it can be extremely difficult to determine the optimum product mix from the available supply of logs. An American study by K.D. Ramsing from the University of Oregon used linear programming (LP) for a veneer-to-plywood application, and then compared results with actual production in a medium-sized plywood firm. The LP solution indicated the company concerned should have produced only 17 grades and thicknesses, instead of the actual 58, and could have more than doubled its profit by following the LP optimum mix.

Venply, a linear programming optimisation model for veneer and plywood production, planning and marketing, is being developed by Noli Sicad, a postgraduate student at the Canterbury School of Forestry, with assistance from Dr Graham Whyte and Robert Donnelly.

Paul Cane, manager of Carter Holt Harvey Timber's plywood plant in Tokoroa, says although *Venply* has some way to go before it is fully developed and operational, the company is already using it as a guideline for log purchasing.

"We have many log suppliers, and there are a number of different log grades. Depending on our market mix at the time, we need to know what are the best log resources to buy, and the prices we can afford, in order to maximise returns," says Cane.

Venply, implemented in spreadsheet format, and supported with business graphics such as bar charts and pie graphs, ties in everything, from veneer output from the different log sources to the various grades of plywood made and then sold in the marketplace.

Whyte says the running of *Venply* has been aimed deliberately at the manager doing so independently of any researcher or operational research expert. The input and output reports are all in a form that managers work with daily.

Cane says that before adopting *Venply*, their decisions were based on very basic spreadsheets.

"*Venply* is already helping us with log purchasing. When fully operational, we'll be more efficient in our decision making on obtaining the optimum mix from available resources, in line with what the market wants," says Cane. EI